AD-A256 664

(2)

Final
Environmental Impact Statement

Volume 3
Methodology Development

Appendices 3-1 through 3-8

BOMARC MISSILE SITE
McGuire Air Force Base
New Jersey

HEADQUARTERS MILITARY AIRLIFT COMMAND
(HQ MAC/LEVC)
Scott Air Force Base, Illinois 62225
(618) 256-5763

May 1992

CURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

a. REPORT SECURITY CLASSIFICATION
Unclassified

1b. RESTRICTIVE MARKINGS
N/A

a. SECURITY CLASSIFICATION AUTHORITY
N/A

3. DISTRIBUTION/AVAILABILITY OF REPORT
Approved for public release; distribution is unlimited.

b. DECLASSIFICATION/DOWNGRADING SCHEDULE
N/A

. PERFORMING ORGANIZATION REPORT NUMBER(S)
N/A

5. MONITORING ORGANIZATION REPORT NUMBER(S)
N/A

a. NAME OF PERFORMING ORGANIZATION
The Earth Technology Corporation

6b. OFFICE SYMBOL
(if applicable)

7a. NAME OF MONITORING ORGANIZATION
AFCEE ESO/ER

c. ADDRESS *(City, State, and ZIP Code)*
300 N. Washington St., #700, Alexandria, VA 22314

7b. ADDRESS *(City, State, and ZIP Code)*
Brooks AFB, Texas 78235-5501

a. NAME OF FUNDING/SPONSORING ORGANIZATION
AFCEE

8b. OFFICE SYMBOL
(if applicable)
ESO/ER

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
F33615-90-D-4007

c. ADDRESS *(City, State, and ZIP Code)*
Brooks AFB, Texas 78235-5501

10. SOURCE OF FUNDING NUMBERS

Program Element No.	Project No.	Task No.	Work Unit Accession No.

1. TITLE *(Include Security Classification)*
Environmental Impact Statement for BOMARC Missile Site, McGuire AFB, New Jersey Volume[redacted] 3

2. PERSONAL AUTHOR(S)
Hastings, T., McKenzie-Carter, M., Ryan, D., Smith, J., *et al.*

3a. TYPE OF REPORT
Final

13b. TIME COVERED
FROM 89/11 to 92/5

14. DATE OF REPORT *(Year, Month, Day)*
1992 May 22

15. PAGE COUNT

6. SUPPLEMENTARY NOTATION

7. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
Environmental Impact Statement

9. ABSTRACT *(Continue on reverse if necessary and identify by block number)*
his document consists of the final EIS report for the BOMARC Missile Site, McGuire AFB, New Jersey. The BOMARC Missile Site became contaminated in 1960 s the result of a fire which partially consumed a nuclear warhead-equipped with BOMARC missile. The EIS evaluates the potential environmental impacts of the arious alternatives proposed to affirmatively address the radioactive contamination at the BOMARC Missile Site. Of the alternatives evaluated, the Air Force's referred alternative is the excavation and off-site disposal of contaminated soils, sediments, and structural materials.

0. DISTRIBUTION/AVAILABILITY OF ABSTRACT
☒ Unclassified/Unlimited ☐ Same As Rpt. ☐ DTIC Users

21. ABSTRACT SECURITY CLASSIFICATION
Unclassified

2a. NAME OF RESPONSIBLE INDIVIDUAL
Major John M. Clegg, Jr. P.E.

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22c. OFFICE SYMBOL
AFCEE/ ESO/IR

Form 1473, JUN 86 *Previous editions are obsolete.*

SECURITY CLASSIFICATION OF THIS PAGE

Final
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1.0 INTRODUCTION

This document was prepared in order to support the analysis provided in the Environmental Impact Statement (EIS). The objective of this document is to supplement the EIS by providing the reader with additional information to augment and support the analysis provided in the EIS.

The objective of this document is to provide the reader of the EIS additional information relative to the soils and the geology portions of the EIS. This document is organized into eight sections. The purpose of each section is summarized below.

- Geology and Soils Resource Description - This section provides the reader with the complete comprehensive description of the geologic and soils resource, developed for use in the EIS.

- Data Sources Identification - This section identifies the data sources that were utilized during preparation of the EIS.

- Methods for Assessing Existing Baseline Conditions - This section outlines the field work that was conducted specifically for the EIS to further characterize the baseline geology and soils at the site.

- Methods for Assessing Soils Impacts - This section outlines the review and analysis that were performed in support of the analysis provided in the EIS.

- Levels of Impact Criteria - This section describes the quantitative and qualitative measures that were utilized to assign a rank order to a potential impact.

- Significance Criteria - This section outlines the Council on Environmental Quality (CEQ) Qualitative Criteria that were evaluated to determine the significance of an impact.

- References.

2.0 GEOLOGY AND SOILS RESOURCE DESCRIPTION

The geology and soils resource description provides a summary of the existing information concerning the geology and soils at the BOMARC Missile Site.

2.1 Geologic Resources

The description of the geologic resources includes summaries of (1) the physiographic setting; (2) descriptions of the rock units beneath the BOMARC Missile Site; (3) a general depositional history of the bedrock geology; (4) the seismic and tectonic setting; (5) geotechnical and engineering properties of the formations.

2.1.1 Physiographic Setting

The BOMARC Missile Site is situated in the Atlantic Coastal Plain Physiographic Province. In New Jersey, the Coastal Plain Province is composed of a wedge of clay, sand and gravel units dipping gently to the east. The units range in age from the Cretaceous Period to the Holocene Epoch. Most are glauconitic and several are fossiliferous. In Ocean County, the Coastal Plain sediments range in thickness from approximately 1,000 feet in the northern part of the county at New Egypt to approximately 4,000 feet in the southern part of the county at Tuckerton. The sedimentary deposits are underlain by crystalline bedrock composed of a sequence of metamorphic gneiss and schist. The age of these units range from the Precambrian Era to the early Paleozoic Era.

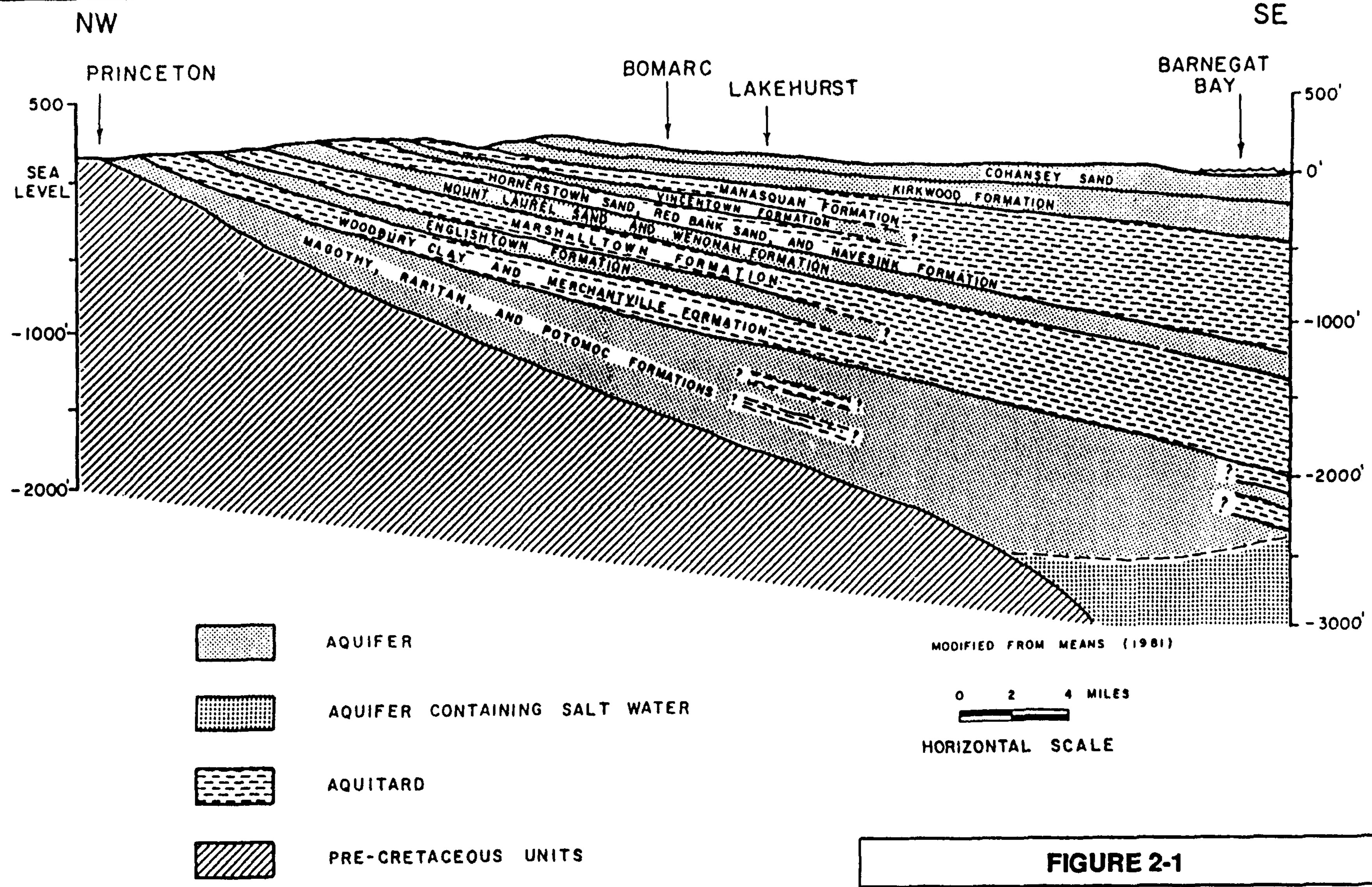
2.1.2 Stratigraphy

The stratigraphy of the BOMARC Missile Site (Figure 2-1) is dominated by interbedded continental and marine sands and clays. Figure 2-2 is a geologic time chart which details the following referenced geologic time periods. The unit at ground surface is a relatively thin expression (40 feet or less) of the Cohansey Sand, underlain by 50 to 60 feet of the Kirkwood Formation. Table 2-1 provides the orientations of the strikes and dips represented in the stratigraphic diagram in Figure 2-1. The following descriptions are for the formations (from youngest to oldest) known to underlie the Atlantic Coastal Plain (Lyttle and Epstein, 1987). The thicknesses given are usually ranges. In most cases, the thickness of a particular formation in this area will be nearer the lower number due to the general formational thinning toward the western border of the province.

The Cohansey Sand (Pliocene Epoch and Miocene Epoch; see Figure 2-2 for geologic time chart) is a light-gray to yellowish-brown, well-sorted, cross-bedded, pebbly, fine- to coarse-grained, ilmenitic, partly arkosic quartz sand, often cemented locally with iron oxide (limonite). Small seams of dark, massive, carbonaceous, kaolinitic and illitic silty clays are interbedded within the sands. Crossbedded gravels are found in channels with quartz and quartzite pebbles. Near the coast, the gravels can reach thicknesses of 150 feet. Thickness is most likely closer to 50 feet near the BOMARC Missile Site. This formation forms the surface or near-surface aquifer in much of the region.

The Kirkwood Formation (Miocene) consists of light gray to yellow-brown, moderately well-sorted, pebbly, lignitic, micaceous, fine- to very-fine-grained quartz sand. It often contains kaolinitic clay or silt, with local thick beds of clayey silt and fine-pebble gravels. There is a basal unit of pebbly, fine quartz sand or medium gray to dark brown, lignitic quartz silt and sand. The formation thickness at the BOMARC Missile Site is 50 to 60 feet. This formation is hydraulically connected to the Cohansey, and together they form the surface or near-surface aquifer in the area.

The Manasquan Formation (Eocene) is a thick-bedded to massive, silty and clayey glauconitic and quartzose sand, interbedded with silty clay and clayey silt. Apatite pellets and siderite fragments may be locally abundant. Thicknesses range from 20 to 195 feet. This formation is the first aquitard below the surface.



VERTICAL SCALE GREATLY EXAGGERATED.

THICKNESSES ARE ONLY APPROXIMATED.

Source: Battelle, 1988.

FIGURE 2-1

NEW JERSEY COASTAL PLAIN STRATIGRAPHY

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Time term	Epoch	Period		Era	
Rock term	Series	System			
	Recent	Quaternary		Cenozoic	
	Pleistocene	Quaternary		Cenozoic	
2 m.y.	Pliocene	Tertiary		Cenozoic	
7 m.y.	Miocene	Tertiary		Cenozoic	
26 m.y.	Oligocene	Tertiary		Cenozoic	
37 m.y.	Eocene	Tertiary		Cenozoic	
53 m.y.	Paleocene	Tertiary		Cenozoic	
		Cretaceous		Mesozoic	65 m.y.
136 m.y.		Jurassic		Mesozoic	
190 m.y.		Triassic		Mesozoic	
		Permian		Paleozoic	225 m.y.
280 m.y.		Carbon-iferous	Pennsyl-vanian	Paleozoic	
320 m.y.		Carbon-iferous	Missis-sippian	Paleozoic	
345 m.y.		Devonian		Paleozoic	
395 m.y.		Silurian		Paleozoic	
430 m.y.		Ordovician		Paleozoic	
500 m.y.		Cambrian		Paleozoic	
		Precambrian			570 m.y.

Source: Press & Siever, 1982.

FIGURE 2-2

GEOLOGIC TIME SCALE

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Table 2-1
Attitudes of Select New Jersey Coastal Plains Formations, Calculated on the Basal Beds of the Formations

Age	Formation	Average Strike (Degrees)	Average Dip (feet/mile)
Tertiary	Cohansey	N72E	SE 10
Tertiary	Kirkwood	N70E	SE 18
Tertiary	Manasquan	N62E	SE 25
Tertiary	Vincentown	N56E	SE 30
Tertiary	Hornerstown	N53E	SE 45
Cretaceous	Red Bank	N47E	SE 35
Cretaceous	Navesink	N47E	SE 35
Cretaceous	Mount Laurel	N47E	SE 35
Cretaceous	Wenonah	N46E	SE 35
Cretaceous	Marshalltown	N46E	SE 35

Source: Battelle, 1988.

The Vincentown Formation (Paleocene) is a light, greenish-brown to brown, fine-grained, glauconitic calcarenite mixed with quartz sand and clay. It is interbedded with dark, greenish-gray to light-gray, medium-grained, glauconitic quartz sand. Thicknesses range from 50 to 100 feet. This formation acts as an aquifer.

The Hornerstown Sand (Paleocene) is a massive, poorly sorted, fine- to medium-grained, locally very silty, clayey glauconite and quartz sand. It may contain phosphate pellets and bone fragments. It is usually about 20 to 30 feet thick. This formation acts as an aquitard.

The Red Bank Sand (Upper Cretaceous) is a very thick bedded, medium- to coarse-grained, fairly indurated, quartz, feldspar, and glauconite sand and fossiliferous sandy silt. Thicknesses can reach 120 feet, but usually range from 10 to 50 feet in the study area. This formation is a major aquitard in the region.

The Navesink Formation (Upper Cretaceous) consists of dark-gray, thick-bedded, clayey and silty, glauconitic sand, with organic matter, pyrite, and locally thick shell beds. Thicknesses can reach 45 feet, but usually range from 20 to 25 feet. This formation is an aquitard.

The Mount Laurel Sand (Upper Cretaceous) consists of a medium-grained, poorly to moderately sorted, feldspathic quartz sand. It contains abundant borings filled with glauconite sand and thin-bedded, dark, micaceous and carbonaceous silt and clay alternating with medium-bedded, light-colored, micaceous, glauconitic quartz sand with discontinuous layers of gray siderite concretions. Thicknesses can reach 20 to 50 feet. This formation is an aquifer.

The Wenonah Formation (Upper Cretaceous) is a generally dark, thick-bedded, fine- to medium-grained, poorly to moderately sorted, carbonaceous, pyritic, very silty and clayey, quartzose glauconite sand. Thicknesses range from 20 to 100 feet. This formation is an aquifer.

The Marshalltown Formation (Upper Cretaceous) is a dark, fine-grained, massive, fossiliferous, very silty and clayey, quartzose glauconite sand. It often contains mica, feldspar, pyrite, and carbonaceous matter. Thicknesses range from 15 to 20 feet. This formation is an aquitard.

The Englishtown Formation (Upper Cretaceous) consists of light-colored, well-sorted, fine- to medium-grained, crossbedded, glauconitic, feldspathic, and micaceous quartz sand. It contains interbedded clayey silt and sand with numerous siderite concretions. Thicknesses range from 20 to 150 feet. This formation is an aquifer.

The Woodbury Clay (Upper Cretaceous) is a dark-gray, massive to crudely laminated, carbonaceous, pyritic, partly glauconitic, micaceous, very clayey (dominantly illitic) silt. Thicknesses can reach 100 feet. This formation is an aquitard.

The Merchantville Formation (Upper Cretaceous) is a dark, clayey, micaceous, quartzose, carbonaceous silt, interbedded with gravel containing reworked siderite concretions. It also contains thick-bedded glauconite and quartz sand. Thicknesses range from 20 to 100 feet. This formation is an aquitard.

The Magothy Formation (Upper Cretaceous) is a dark, micaceous, pyritic, kaolinitic, clayey silt and light-colored quartz sand with large lignitized logs. Thicknesses range from 10 to 200 feet.

2.1.3 Bedrock Geology

The Atlantic Coastal Plain is a gently seaward-sloping surface characterized by a series of poorly consolidated, marginal marine sediments that thicken to the southeast and range in age from Recent to Cretaceous. Underlying these sediments is Precambrian crystalline metamorphic bedrock.

The Coastal Plain sediments are mixed marine and nonmarine. At the time these Cretaceous formations were deposited, the Atlantic Ocean had essentially its present form. Additional sediments were deposited during the Tertiary Period. Subsidence of the entire area to the southeast during both Cretaceous and Tertiary deposition formed a thick wedge of sediments that thickens to the southeast. A final thin, discontinuous veneer of sediments covers parts of the area.

2.1.4 Seismic and Tectonic History

Historically, the seismic activity in the region surrounding the BOMARC Missile Site has been slight to moderate as shown on Figure 2-3; Table 2-2 explains the Modified Mercalli Scale. According to information provided by the United States Geological Survey (Seismicity Map of the State of New Jersey, Stover, *et al.*, 1987), there have been no severe earthquakes (i.e., causing severe damage to dikes, dams, roads and other structures) in the region during the past 200 years. However, there have been several small earthquakes with epicenters within 50 miles of the site in the past 100 years (Stover *et al.*, 1987). The strongest such earthquake occurred in 1927 about 50 miles to the northeast of the facility. This earthquake measured VII on the Modified Mercalli (MM) Scale, and was strong enough to break windows and crack chimneys and walls to some extent. In 1938, an earthquake of MM magnitude V took place in the region with its epicenter located about 10 miles northwest of the present BOMARC Missile Site. An earthquake of MM magnitude V is strong enough to be felt by most people, and may overturn small or unstable objects. It may also cause some minor damage, such as broken dishes or glassware. In 1982, another earthquake with an MM magnitude of V occurred about 25 miles west of the facility. A number of smaller earthquakes have occurred in the vicinity of the BOMARC Missile Site within the last century. However, it should be noted that even the strongest of these earthquakes was not strong enough to cause more than very minor damage, such as broken windows and dishes.

The area containing the BOMARC Missile Site is tectonically quiet based on a review of geologic maps and literature published for the region.

2.1.5 Engineering Characteristics

The engineering characteristics of the geologic formations in this area are summarized on Table 2-3. The two geologic units found at the surface (the Cohansey and Kirkwood formations) have been characterized as having poor slope stability and good to excellent internal drainage. This is primarily due to the coarse size fraction and the well sorted nature of these poorly consolidated sediments.

2.2 Soil Resources

The description of the soil resources includes summaries of (1) the various soil types at the BOMARC Missile Site and vicinity; (2) the geotechnical and engineering properties of these soils; and (3) a qualitative discussion of the potential for soil erosion.

2.2.1 Soil Series

There are several soil types in the vicinity of the BOMARC Missile site, as shown on Figure 2-4. The main soil types which are in the soil Region of Influence (ROI) are described in detail below.

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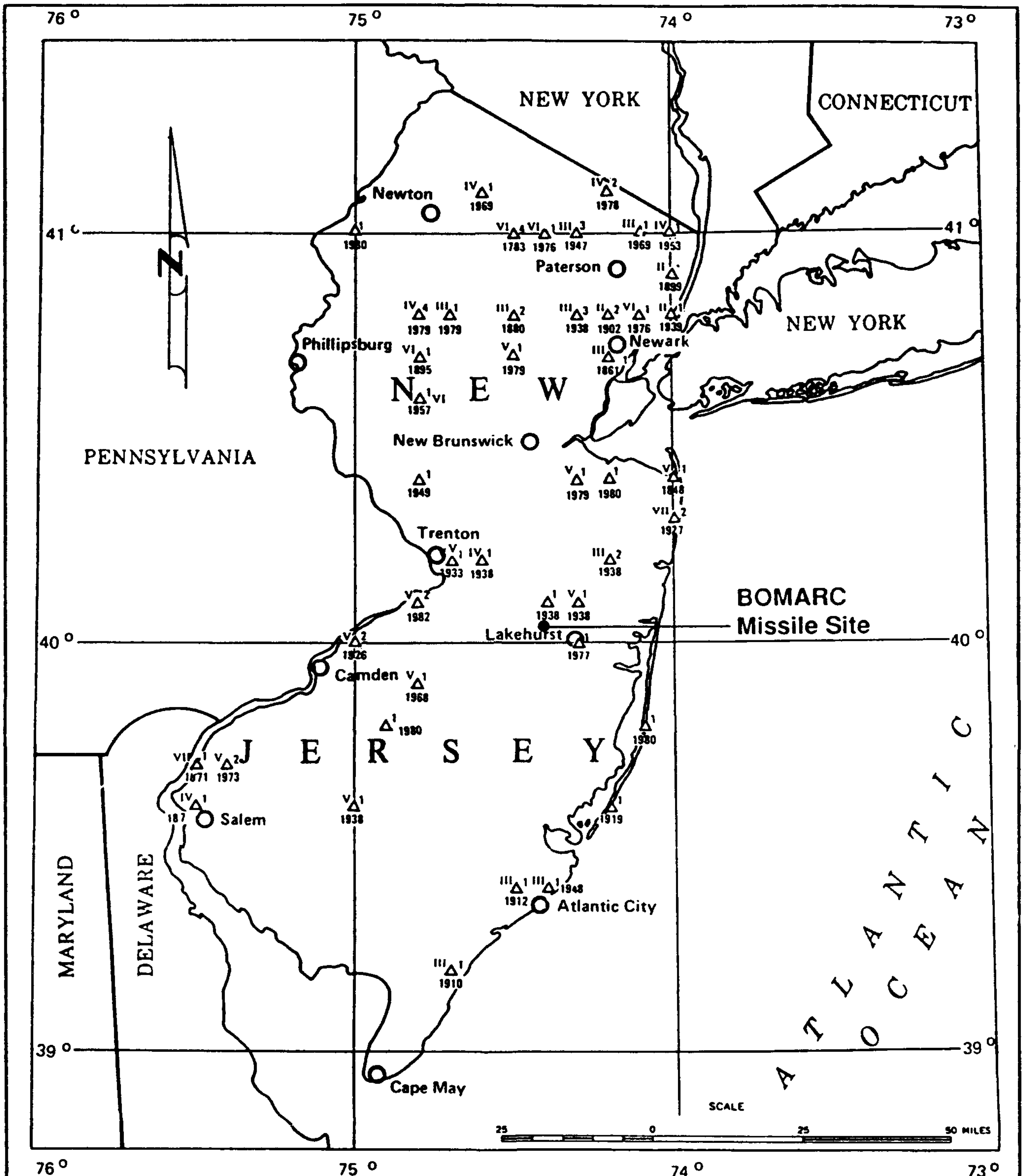

LEGEND

Δ - Earthquake Epicenter Location

Roman Numerals - Earthquake Magnitude on Modified Mercalli Intensity Scale

Arabic Numbers - The Number of Earthquakes at each location

Source: Stover, et al, 1987.

FIGURE 2-3

LOCAL SEISMIC ACTIVITY NEAR THE BOMARC MISSILE SITE

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Table 2-2
Explanation of Modified Mercalli Intensity Scale Categories

I.	Seismic activity is rarely noticed. Trees, structures, and bodies of water may sway.
II.	Seismic activity may be felt indoors, especially on upper floors. Grade I characteristics may occur, but to a more noticeable degree. Hanging objects may swing, and trees, structures, bodies of water, and doors may sway.
III.	A rapid vibration is often felt indoors. Noticeable movement may be appreciable on upper levels of tall structures. A vibration similar to that caused by the passing of a heavy truck may be felt. Hanging objects may swing and standing automobiles may be slightly rocked.
IV.	Seismic activity may be felt both indoors and outdoors. A vibration similar to that caused by the passing of a heavy truck may be felt. Dishes, windows, and doors may rattle and walls and structural frames may creak.
V.	Seismic activity may be felt indoors and outdoors. Trees and bushes may be shaken slightly and dishes and windows may break. Movement of small objects and furnishings may also be observed.
VI.	Seismic activity is felt indoors and outdoors. Resulting destruction may consist of cracked plaster, broken dishes, and structural damage to poorly built buildings. Furniture may be overturned, dishes may break, and church bells may ring.
VII.	Movement may be noticed by auto drivers. Waves may be observed on ponds, lakes, and running water. Observed damage may be negligible in well-built structures, however, damage may be considerable in poorly built buildings, adobe houses, old walls and spires. Heavy furniture may be overturned.
VIII.	Seismic activity is noticed by auto drivers. Trees are shaken strongly. Level ground and steep slopes may become noticeably wet and sand and mud may be ejected from the ground. Changes may occur in the flow of springs and wells, including renewed flow in dry wells and water temperature fluctuations. Slight damage to brick, earthquake-proof structures may occur. Partial collapse of wooden structures, cracking of solid stone walls, and overturned heavy furniture may occur. Fallen chimneys, columns, monuments, factory stacks and towers may occur.
IV.	Seismic activity causes visible cracks in the ground. Masonry earthquake-proof structures may show considerable damage. Wood-frame earthquake-proof structures may be thrown out of plume. Some structures may shift off of foundations or collapse. Damage may be great in large masonry buildings. Underground pipes may break and reservoirs may be unstable.
X.	Seismic activity may cause the ground to form cracks up to several inches in width and may cause yard-width fissures to form parallel to canal and stream bands. Horizontal shifting of sand and mud on beaches and flat land, landslides from river banks and steep coasts, and broad folds in cement pavements and asphalt road surfaces may occur. Disturbances in water bodies may be observed, well water level fluctuations may occur, and serious damage to dam, dikes, and embankments may result. Resulting damage may range from severe to total destruction of wooden bridges and masonry structures and their foundations. Underground pipes may be torn apart or crushed endwise and railroad rails may bend slightly.

(Continued)

Table 2-2
Explanation of Modified Mercalli Intensity Scale Categories
(Continued)

XI. Widespread ground disturbances occur. Broad fissures, earth slumps, land slides in soft, wet ground, and ejected water charged with sand and mud may be observed. Sea-waves of significant magnitude may result. Great damage to dikes, dams, and embankments in outlying areas, relative to the epicenter, may also occur. Few masonry structures may remain standing. Severe damage to wood-frame structures may occur, and disruption of bridge support pillars or piers may result in complete destruction of bridges. Wooden bridges may not show damage to this extreme extent. Buried pipe lines may be completely out of service and railroad rails may be significantly bent.

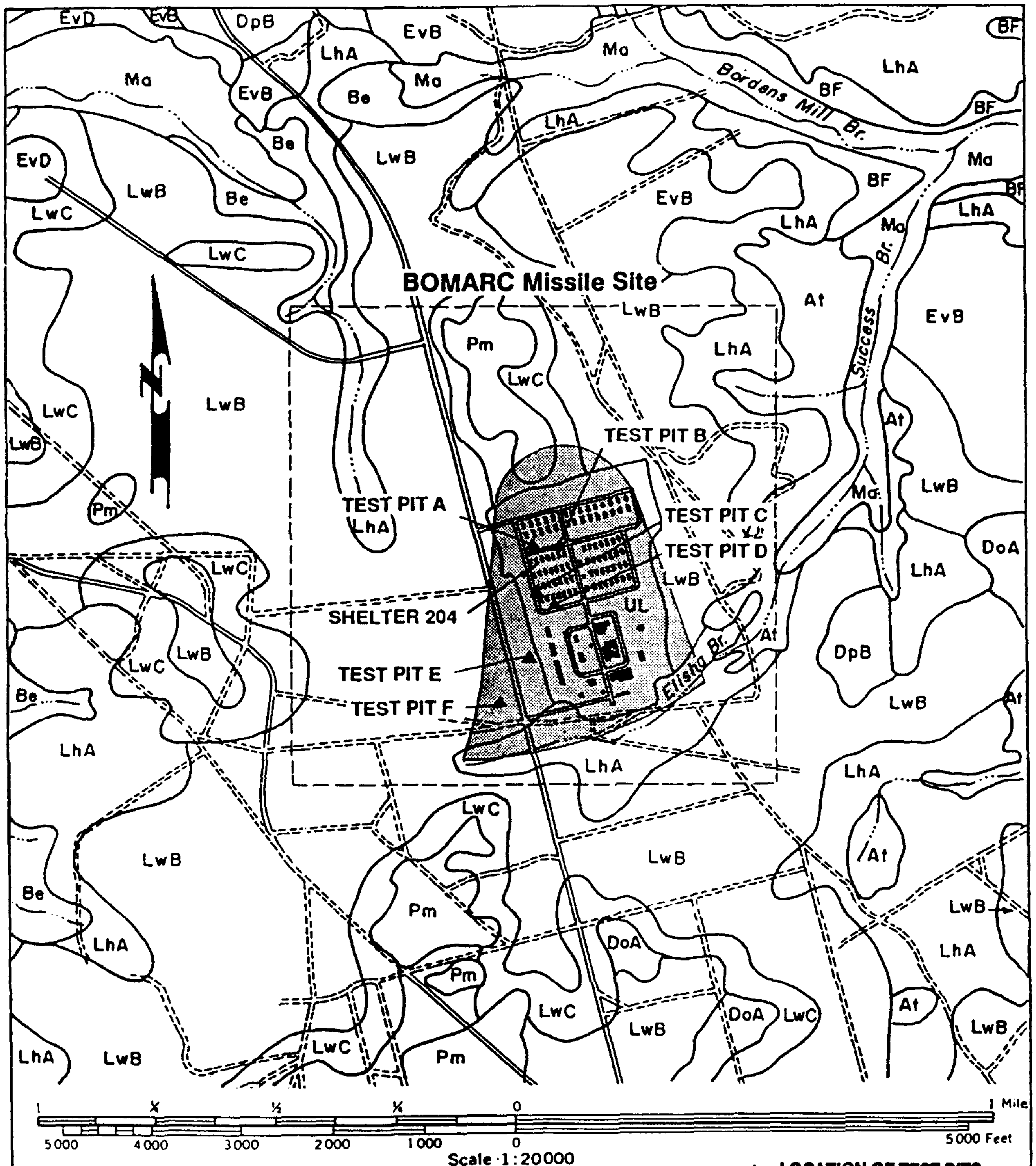
XII. Ground disturbances are great and varied. All works of construction may be greatly damaged or destroyed. Numerous extensive land slides, shearing cracks and river bank slumping occur. Large rock masses are wrenched loose and surface and underground water channels may be greatly modified. Fault slips with notable horizontal and vertical offset displacements may be noticed in firm rock. Lakes may be dammed, waterfalls may be produced and rivers may be deflected. Waves may be seen on ground surfaces, causing distorted lines of sight.

Source: Wood and Neumann, 1931.

Table 2-3
Engineering Characteristics of the Formations Near the BOMARC Missile Site

Formation	Slope Stability	Internal Drainage	Foundation Support	Pavement Support	Use
Cohansey	Poor	Excellent	Good	Good	Mortar sand, concrete aggregate, retaining walls, borrow
Kirkwood	Poor	Good	Good	Good	Retaining walls, borrow, fill, molding sand
Manasquan	Fair	Fair	Fair	Poor to Fair	Fill, source of glauconite
Vincentown	Poor	Good	Good	Good	Borrow, asphalt, sand
Hornerstown	Good	Fair	Good	Fair	Fill, source of glauconite
Red Bank (upper member)	Poor	Good	Good	Good	Borrow
Red Bank (lower member)	Good	Poor	Good	Fair	Fill, source of glauconite
Navesink	Good	Poor to Fair	Good	Fair	Fill, source of glauconite
Mount Laurel	Good	Good	Good	Good	Borrow, asphalt, sand
Wenonah	Poor to Fair	Fair to Good	Good	Good	Fill, molding sand
Marshalltown	Poor to Fair	Poor to Fair	Fair	Fair	Fill

Source: Battelle, 1980.



SOILS

At - Atsion sand
Be - Berryland sand
BF - Berryland sand, frequently flooded
DoA - Downer loamy sand, 0% - 5% slopes
DpB - Downer sandy loam, 2% - 5% slopes
EvB - Eversboro sand, 0% - 5% slopes
EvD - Eversboro sand, 10% - 15% slopes
LhA - Lakehurst sand, 0% - 3% slopes
LwB - Lakewood sand, 0% - 5% slopes
LwC - Lakewood sand, 5% - 10% slopes
Ma - Manahawkin muck
Pm - Pits, sand & gravel
UL - Urban Land

Soil Region of Influence

▲ LOCATION OF TEST PITS

Source: Hole and Smith, 1980.

FIGURE 2-4

SITE SOIL REGION OF INFLUENCE, SOIL TYPE, AND TEST PIT LOCATION MAP

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Lakewood Series

The Lakewood series (Hole and Smith, 1980) is the predominant natural soil series in the BOMARC Missile Site area (Figure 2-4). The Lakewood soils consist of 7 to 10 inches of gray sand overlying 20 to 25 inches of dark brown to yellowish-brown sand to a depth of about 60 inches. These soils are characterized as excessively drained; they are coarse, conducive to rapid water percolation, and have low moisture retention and low nutrient content. Permeabilities range from 0.2 to 6.3 inches per hour.

The Lakewood series is a true podzol, which is "a group of zonal soils having an organic mat and a very thin organic-mineral layer overlying a gray, leached A2 horizon and a dark brown, alluvial B horizon enriched in iron oxide, alumina, and organic matter. It develops under coniferous or mixed forests or under heath, in a cool to temperate moist climate" (Hole and Smith, 1980). In the Lakewood Series, the sodium, calcium, and magnesium have been dissolved, and the less soluble iron, aluminum, and titanium are partially leached and precipitated into the subsoil. A representative chemical analysis of Lakewood soil is provided in Table 2-4.

Table 2-4
Chemical Analysis of BOMARC Missile Site Soil Samples

Analyte	Lakewood Soil	Urban Land Soil
Aluminum	520 - 1490 μg/gram	540 - 1090 μg/gram
Calcium	30 μg/gram	110 - 360 μg/gram
Iron	1650 - 2530 μg/gram	433 - 1040 μg/gram
Magnesium	4 - 11 μg/gram	6 - 12 μg/gram
Organic Matter	4.6 - 17.6%	7.9 - 18.9%
Moisture	4.0 - 8.0%	1.4 - 6.0%

Urban Land Unit(s)

As a consequence of Base development/construction activities the predominant category of soil on the site is mapped as "sandy urban land". Urban land map units are generally so variable that their properties are not characterized by the Soil Conservation Service. Use constraints are probably severe due to the great permeability in the unit(s). A chemical analysis of the Urban Land soils provided as Table 2-4.

Lakehurst Series

The Lakehurst series soils are located in the southern area of the site (Figure 2-4). The Lakehurst soils consist of 10 to 12 inches of light to dark gray sand overlying 25 to 34 inches of light yellowish to dark brown sand with light gray mottles in its lower part to a depth of about 60 inches. In general, the Lakehurst soils are moderately to somewhat poorly drained (depending on their elevation relative to groundwater), strongly acidic (pH 3.6 to 5.0), of low natural fertility, coarse-grained, and are conducive to rapid water percolation. Permeabilities range from 0.2 to 20 inches per hour.

2.2.2 <u>Geotechnical and Engineering Properties</u>

The geotechnical and engineering properties of the soils within the BOMARC Missile Site ROI are summarized in Table 2-5. Lakewood and Lakehurst soils are characterized as mostly sand with a very low to moderate silt and clay content.

2.3.3 <u>Erosion Potential</u>

In qualitative terms, the potential for water erosion of both the Lakehurst and the Lakewood soils in the BOMARC Missile ROI is moderate. Runoff from Lakehurst soils is low, whereas runoff from Lakewood soils is moderate. However, this coupled with the coarse particle size and low cohesion leaves these soils somewhat vulnerable to detachment and transport by rainfall-runoff events. The low runoff and shallow slopes found in these soils tend to mitigate this erosion potential. In addition to low fertility, low available water capacity, and rapid permeability, the potential for wind erosion is also expected to be moderate.

3.0 DATA SOURCE IDENTIFICATION

In the following sections, existing data sources with respect to the soils and geology at the BOMARC Missile Site are identified. An inventory of site specific soil and/or geological studies for the site are provided.

3.1 Existing Technical Literature

Data sources utilized during the description, definition and mapping of the geologic units and soil units at the BOMARC Missile Site include:

- 1:24,000 U.S. Geological Survey (USGS) topographic maps (Cassville Quadrangle)
- U.S. Geological Survey Geologic Quadrangle Maps (New Egypt Geological Quadrangle and Geologic Map of the Newark 1° × 2° Quadrangle)
- U.S. Geological Survey and New Jersey Geological Survey Geologic Reports
- U.S. Department of Agriculture Soil Conservation Service Soil Survey for Ocean County
- Site Topographic Maps provided by McGuire AFB

Table 2-5
Geotechnical and Engineering Properties of BOMARC Region of Influence Soils

Soil Name and Map Symbol*	Depth (Inches)	U.S. Department of Agriculture Texture	Classification: Unified	Classification: AASHTO**	Fragments > 3 inches	Percentage Passing Sieve Number: 4	10	40	200	Liquid Limit (%)	Plasticity Index	Shrink - Swell Potential
LhA Lakehurst	0 - 12	Sand	SP, SM, SP-SM	A-1, A-2, A-3	0	85-100	80-100	40-80	0-20	—	—	Low
	12 - 46	Sand, fine sand, loamy sand	SP, SM, SP-SM	A-1, A-2, A-3	0	85-100	80-100	40-80	0-30	—	nonplastic	Low
	46- 60	Sand, gravelly sand, sandy loam	SP, SM, SC, SM-SC, SM-SC	A-1, A-2, A-3	0	80-100	70-100	40-80	0-35	<15	nonplastic-5	Low
LwB Lakewood	0 - 10	Sand	SP, SP, SM	A-1, A-2, A-3	0	95-100	90-100	40-90	0-12	—	—	Low
	10 - 36	Sand, fine sand, loamy sand	SP, SM, SP-SM	A-1, A-2, A-3	0	85-100	80-100	40-85	0-30	—	nonplastic	Low
	36 - 20	Sand, gravelly sand, sandy loam	SP-SM	A-1, A-2, A-3	0	85-100	75-100	40-90	0-35	<12	nonplastic-5	—
LwC Lakewood	0 - 11	Sand	SP, SP-SM	A-1, A-2, A-3	0	95-100	90-100	40-90	0-12	—	—	Low
	11 - 28	Sand, fine sand, loamy sand	SP, SM, SP-SM	A-1, A-2, A-3	0	85-100	80-100	40-85	0-30	—	nonplastic	Low
	28 - 60	Sand, gravelly sand, sandy loam	SP, SM	A-1, A-2, A-3	0	85-100	75-100	40-90	0-35	<20	nonplastic	—

SP = poorly graded sands, gravelly sands, little or no fines.
SM = silty sands, poorly graded sand-silt mixtures.
SC = clayey sands, poorly graded sand-clay mixtures.
*No data available for Urban Land (UL).
**American Association of State Highway and Transportation Officials.

- Site Borehole logs developed during previous site characterization program
- Other documents (Regional EISs, Environmental Assessments and independent geological or ecological reports).

Federal and state geological surveys, federal and local soil conservation agencies, local experts, local university geology departments and base environmental personnel were consulted to obtain current information on the site geology and soils.

3.2 Site Specific Studies

In addition to the above regional sources of information, several site specific environmental studies have been carried out at the BOMARC Missile Site. The purpose of these reports has been to characterize the geological and environmental setting at the BOMARC Missile Site and to assess the existence, concentration and extent of any surface and subsurface radioactive contamination that might exist at the site. The site specific studies include:

- Core Boring Data and Test Pit, January 20, 1958, McGuire Special Facility (BOMARC Missile Site), developed by Wigton-Abbott Corp., Newark, NJ and Office of District Engineer, U.S. Army Engineer District, Philadelphia, PA, Drawing No. AW 16-14-01.

- Battelle Columbus Division, December 9, 1988, Draft Work Plan Report, Installation Restoration Program, Stage 2, BOMARC Missile Site, McGuire AFB, NJ.

- Battelle Columbus Division, December 9, 1988, Quality Assurance Project Plan, Draft Report, Installation Restoration Program, Stage 2, BOMARC Missile Site, McGuire AFB, NJ.

- Roy F. Weston, Inc., January 1988, Installation Restoration Program, Phase II - Confirmation/Quantification Stage 2, Volume 1, Draft Report, McGuire AFB, NJ.

4.0 METHODS FOR ASSESSING EXISTING BASELINE CONDITIONS

The types of physical and chemical data from the ROI soils that were acquired specifically for the EIS and the utility of the data are described below:

- Soil Chemistry Data - Six sample points (Figure 2-4) located near Shelter 204 and along the drainage swale were chosen within the soil ROI. Each sample included an approximately equal distribution of soil from 0 to 12 inches below the surface at each sample location. The surface soil samples were chemically analyzed for the following parameters: cation content (iron, calcium manganese and aluminum), soil pH, natural moisture content and organic content. These data aided in defining the soil-plutonium retention and transport capacity.

- Physical Data - Soils were collected at the above sampling stations for particle size determination. This data was used to characterize the site soil-plutonium retention and transport capacity. Because plutonium tends to preferentially adsorb to soil particles in the 5 to 125 micron range, it is important to know the percentage of soil in this size range present in the ROI.

- Test Pits - Six test pits (Figure 2-4) were excavated to characterize the soil stratigraphy and lithology within the ROI. The pit dimensions were approximately 2 feet long, 2 feet wide, and 1.5 feet deep. The test pits were excavated at the above soil chemistry sample locations.

- Sediment - Plutonium migration delineation - A total of 25 sediment samples were collected (as part of the Remedial Investigation/Feasibility Study (RI/FS) data collection) along the drainage pathway downstream along the Elisha Branch.

5.0 METHODS FOR ASSESSING SOILS IMPACTS

Research was conducted to determine the soil properties that are important influences on migration of plutonium and americium, and to identify a soil erosion model that could be used to provide some estimate of potential soil loss. These properties and the soil erosion model are dicussed in Section 3.2.7.4 of the EIS.

6.0 LEVELS OF IMPACT CRITERIA

The level of impact (LOI) criteria for the geology and soils methodology at the BOMARC Missile Site addresses the principle contaminant, plutonium. The LOI for soils employs the 3.0 μCi per m^2 level (the site-specific soil screening level) as a benchmark or means of comparison for the intensity of impact. This screening level was determined in the RI/FS (Appendix J). Listed below are the qualitative descriptions of the four levels of impact for soils that were used to characterize potential impacts at the BOMARC Missile Site:

- <u>Negligible Impact</u> - Activity associated with ^{239}Pu concentrations in the ROI soils is less than or equal to the site-specific soil screening level of 3.0 μCi per m^2. The potential for soil erosion would remain the same.

- <u>Low Impact</u> - Activity associated with ^{239}Pu concentrations in the ROI soils is greater than or equal to the site-specific soil screening level of 3.0 μCi per m^2. The potential for soil erosion would slightly increase.

- <u>Moderate Impact</u> - Activity associated with ^{239}Pu concentrations in the ROI soils is greater than the site-specific soil screening level of 3.0 μCi per m^2. The potential for soil erosion would moderately increase.

- <u>High Impact</u> - Activity associated with ^{239}Pu concentrations in the ROI soils is much greater than the site-specific soil screening level of 3.0 μCi per m^2. The potential for soil erosion would severely increase.

7.0 SIGNIFICANCE CRITERIA

The significance of an impact is determined by evaluating its context and intensity as required under the CEQ regulations (40 Code of Federal Regulations 1508.27). Per CEQ regulations, the following items were considered in evaluating significance of an impact:

- beneficial as well as adverse impacts
- effect on public health and safety
- unique (e.g., historic, scenic, etc.) features of the area
- effects on the environment that are likely to be controversial
- effects on the environment that are uncertain or unknown
- action that establishes a precedent with significant effects
- action that contributes to significant cumulative impact
- adverse effect on scientific, cultural or historic places
- adverse effect on an endangered species
- action that threatens a violation of Federal, state or local law.

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TELEPHONE CONVERSATION LOG

Bicki, T., Soil Science Professor, University of Illinois at Urbana IL, May 9, 1989.

Dyke, P., Soil Scientist, Texas Agricultural Experimental Station, April 3, 1989.

Hakonson, T., Los Alamos Test Site, Los Alamos, NM, April 17, 1989.

Knisel W., Hydrologist, Southeast Watershed Research Lab, Tifton, GA, April 17, 1989.

Olson, K., Soil Science Professor, University of Illinois at Urbana, IL, April 14, 1989.

Solbeck, T., Soil Scientist, Texas Soil Research Station, May 9, 1989.

Tibitz, Soil Engineer, U.S. Soil Conservation Service, Somerset, NJ, April 4, 1989.

Appendix 3-2

Hydrology Methodology Development Report

May 1992

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1.0 INTRODUCTION

This document was prepared to support the analysis provided in the Environmental Impact Statement (EIS). The objective of this document is to supplement the EIS by providing the reader with information to augment and support the analysis provided in the EIS.

The objective of this methodology is to satisfy the hydrologic portion of the Environmental Impact Analysis Process for addressing radioactive contamination at the BOMARC Missile Site. The scope includes the following:

- a hydrology resource description
- data source identification
- the methodology for assessing baseline conditions
- the methodology for assessing hydrologic impacts
- impact criteria identification
- significance criteria identification.

2.0 HYDROLOGY RESOURCE DESCRIPTION

The hydrology resource description provides: (1) a hydrologic characterization of surface water bodies at the site and vicinity, including natural and man-made drainages, flow conditions, water quality, flood conditions and use; (2) a hydrogeologic characterization of the groundwater system beneath the site focusing on aquifer properties, flow directions and rates, monitoring systems, water quality and resource use; and (3) a description of the region of the hydrologic system that may be affected by the proposed action or alternatives. The resource description relies on available site-specific information provided in existing reports (USAFOEHL, 1986; Weston, 1988; Battelle, 1988) and the Remedial Investigation/Feasibility Study (RI/FS) report, which is a companion document to this EIS.

2.1 Surface Water Hydrology

There are several features of the surface water system which are described in order to characterize the hydrology at the BOMARC Missile Site. First, general surface water hydrology features of the site are described (including the regional setting and nearby water bodies). Then, the local watershed drainage areas, flow characteristics, flood conditions, and artificial water control systems are described. Finally, a description of surface water quality is provided.

2.1.1 Surface Water Features

The BOMARC Missile Site is located near the northern boundary of the New Jersey Pinelands in the outer portion of the Atlantic Coastal Plain Physiographic Province. The coastal plain and Pinelands terrain is characterized by gently rolling hills and low-lying, poorly drained wetland environments. The BOMARC Missile Site occupies one of a series of north-south trending hills or highlands which are flanked to the east and west by broad lowlands, i.e., swamps marshes and bogs (see Figure 2-1). The highlands are dry and sandy, and therefore are conducive to

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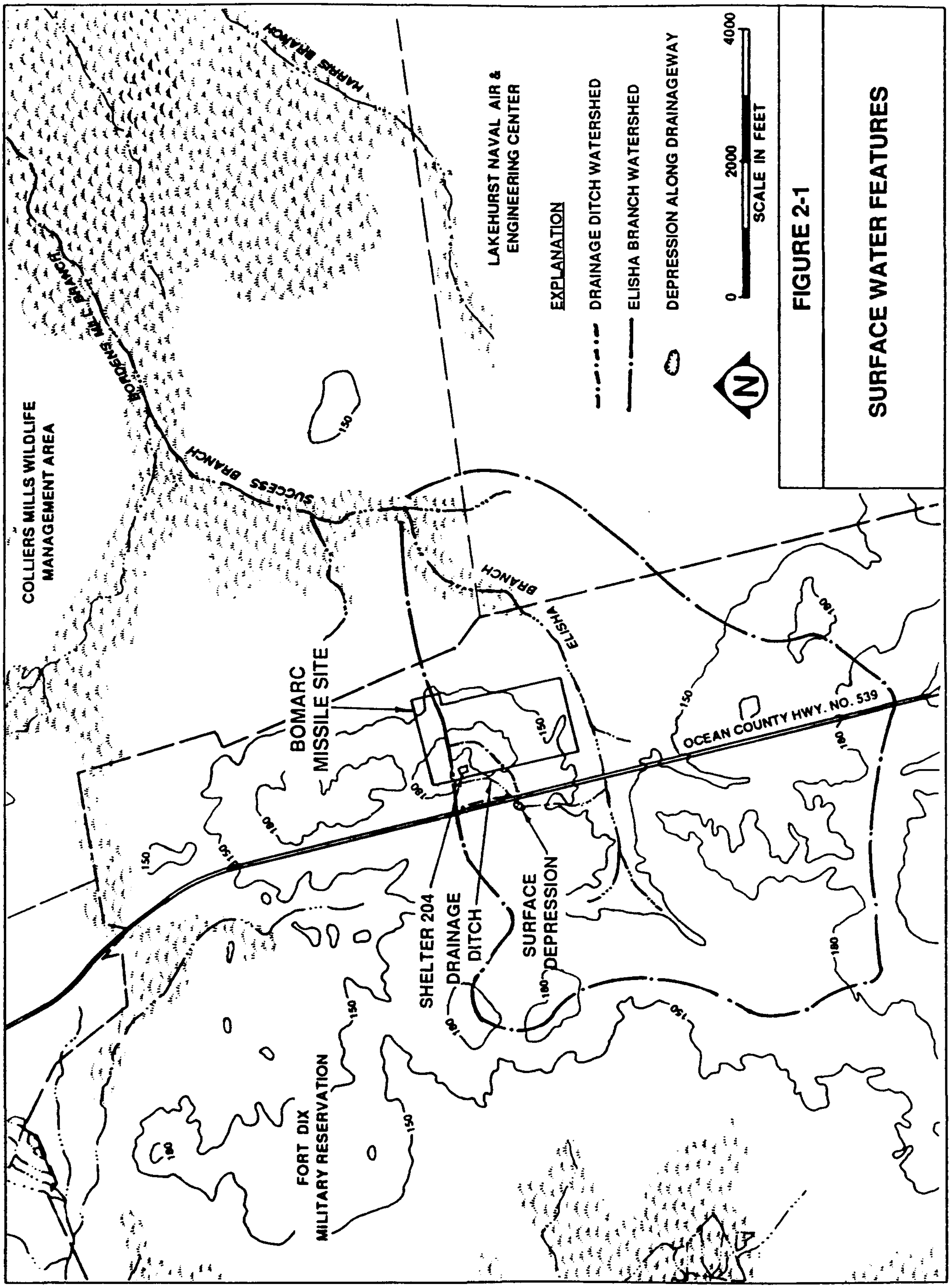

FIGURE 2-1

SURFACE WATER FEATURES

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rapid infiltration of precipitation. The lowlands are water-saturated swamps which release water slowly to drainageways as base flow. Base flow represents the portion of stream discharge derived from groundwater seepage.

There are no permanent surface water bodies on the dry, upland soils of the BOMARC Missile Site. The principal surface water features associated with the site are the natural streams that drain the nearby low wetlands of the Pinelands. A majority of the surface runoff from both the missile launch area and support facilities drains to the west, south and east eventually reaching Elisha Branch. From Elisha Branch surface water flows into larger tributaries leading to Ridgeway Branch, Toms River and ultimately the Atlantic Ocean via Barnegat Bay. Major water bodies in the watershed include Success Lake and Horizon Lake. On the basis of available topographic maps, no significant runoff from the site appears to flow to the north.

In the vicinity of Shelter 204, surface water runoff resulting from precipitation will flow westerly over concrete and asphalt and collect in a north-south trending drainage ditch which borders the paved area. The ditch carries storm runoff to the southwest beyond the site boundary.

Drainage into the ditch is intermittent, depending on the intensity and duration of precipitation events. The amount of flow that eventually reaches the Elisha Branch is variable depending on the losses due to evapotranspiration and infiltration into the ground.

2.1.2 Watershed Drainage Areas

The watershed area for the Elisha Branch just west of the BOMARC Missile Site is approximately 1.4 square miles (see Figure 2-1). The drainage area for the Toms River watershed at Barnegat Bay is 192 square miles. The watershed area of the small drainage ditch located to the west of Shelter 204 and upstream (east) of the culvert beneath Ocean County Highway No. 539 is estimated to be 22 acres. Most of the storm runoff entering the drainage ditch is likely to be derived from the impervious asphalt and concrete surfaces that cover the launch area representing only about half of the 22 acre watershed area. The man-made physical setting favors rapid runoff events and peak discharge with negligible infiltration to groundwater.

2.1.3 Watershed Flow Characteristics

The average annual precipitation in the Pinelands area (including the BOMARC Missile Site) is 44 inches. Estimates of average evapotranspiration are 42 percent (Battelle, 1988) and 50 percent (Rhodehamel, 1970). An estimate of overland runoff is 6 percent (Rhodehamel, 1970), suggesting that the remaining precipitation (less than or equal to 50 percent) infiltrates to the groundwater flow system. Thus, a large portion of the water that reaches the Elisha Branch and other water-courses in the Toms River watershed is derived from base flow of groundwater.

The mean annual discharge for the Toms River at the community of Toms River (drainage area of 124 square miles) is 214 cubic feet per second (cfs), which is a discharge per unit area of 1.73 cubic feet per square mile of watershed (csm). Since the amount of precipitation and the geologic setting are relatively uniform over the Pinelands region, watersheds with higher discharge per unit have greater groundwater flow contribution to surface water courses than

watersheds with lower discharge per unit area. Gaging station records for several rivers in the Pinelands show the Toms River discharge is near the mean for the region, where the range is from 1.37 to 3.81 csm (Means *et al.*, 1981).

There are no historical flow measurements for the Elisha Branch or the immediate drainage area of the BOMARC Missile Site. It is difficult to obtain flow data in the vicinity of the site because the drainage area is small and streamflow is intermittent. Most of the precipitation falling in the immediate watershed area of Shelter 204 (paved areas) is likely to leave the site as runoff. On the basis of the size of the watershed (22 acres), an average annual precipitation of 44 inches per year, and the assumption that at least 90 percent of precipitation leaves the watershed as runoff, the average annual volume of runoff water is about 3.16×10^6 cubic feet for the watershed. If this amount of runoff were to flow out of the watershed at a constant rate over the year, it would produce an estimated average flow of 0.1 cfs. From a 22 acre watershed, this would be a mean annual discharge of 2.92 csm, or on the high end of the range of values for the Pinelands region.

Further downstream, additional water will be contributed from overland runoff and road drainage; however, the amount is expected to be small due to the high recharge potential of the native sandy soils. In the Elisha Branch area, the percentage of rainfall which becomes runoff is significantly less than the BOMARC Missile Site alone because of the retention and storage capacity of the natural wetlands.

2.1.4 Flood Conditions

The BOMARC Missile Site is located on high ground which is not subject to flooding. Significant flooding along the Elisha Branch is unlikely due to the limited runoff from upland areas. Further, the potential for flooding is low because the site is at the headwaters of this drainage area, where the initial runoff input to stream flow occurs.

The low flood potential of the BOMARC Missile Site is expected to be representative of the Pinelands region. As stated previously, the geologic conditions of the Pinelands allow about six percent of the average annual precipitation to flow as direct runoff from the land. Most of the stream flow is comprised of groundwater base flow. Consequently, major floods are not common. The principal time of the year for high water conditions is in early spring. During the rest of the year, stream flow is relatively uniform as a result of steady groundwater discharge.

2.1.5 Control Systems

The BOMARC Missile Site is located at the head-waters of the Elisha Branch. Consequently, there are no control systems (i.e., structures, diversion, etc.) upstream of the site. Along the Elisha Branch and the downstream watercourses leading to the Toms River, the channel is natural. The only artificial controls of surface runoff at the site and vicinity are: (1) road culverts, (2) a depression located on the west side of Ocean County, Highway No. 539 across from the BOMARC Missile Site, and (3) the asphalt/concrete pavement placed in the drainage ditch and in the vicinity of Shelter 204. At the time of the 1960 fire, an earthen berm was

reportedly placed across the drainage ditch to capture contaminated runoff water. The berm was subsequently removed and the drainage channel reopened to carry runoff from the site.

The artificial control systems influence runoff in the following ways:

- The asphalt and concrete cover favor rapid runoff from the site, however, the area covered is protected from erosion and transport of contaminated sediments.
- Some restriction to flow may occur at the upstream side of road culverts resulting in ponding and augmented infiltration into the ground.
- Recharge of surface water into the ground likely occurred on a short-term basis while drainage ditch was temporarily dammed by the earthen berm.
- Additional recharge over the long term is expected in the depression located at the downstream side of the culvert under Ocean County highway No. 539. The depression reportedly collects storm runoff forming a temporary pond which, in turn, allows water to infiltrate into the ground.

2.1.6 Water Quality

Surface water quality information is not available for the BOMARC Missile Site and nearby natural drainageways. However, water quality information is available for the Pinelands region, which includes the Toms River watershed and the Pinelands environment.

The Pinelands region contains naturally acidic water due to the low buffering capacity of the sandy soils and the organic acids released from the decaying vegetation. Surface waters in the Pinelands typically have pH values ranging from 3.5 to 4.5. In undeveloped areas, pH values have declined slightly over the past decade. In developed areas, monitoring during the period from 1977 to 1985 has shown significant increases in pH due to sewer discharges, agricultural drainage and landscaping for new developments (Robinson, 1986).

Because of the acidity of the Pinelands surface waters, iron is readily dissolved from organic compounds present in decaying forest litter. The New Jersey Geological Survey (Means *et al.*, 1981) found surface waters in the Pinelands to contain a low 20 to 35 parts per million (ppm) of total dissolved solids, including the presence of iron. Base flow contributions from groundwater with low dissolved oxygen (DO) and high concentrations of dissolved iron results in coloration of the water due to precipitation of iron upon its aeration at the surface. Organic tanning from the decay of vegetation also contributes to coloration. In spite of the acidic condition of the Pinelands surface waters, New Jersey considers the area to be a valuable reserve of good quality water. A table of maximum and minimum concentrations of chemical concentrations and physicochemical properties of the Pinelands region surface waters is presented in Annex A (Rhodehamel, 1970).

The Toms River watershed drains a large portion of the Pinelands, and contains good to excellent water quality according to the State Water Quality Inventory Report (Robinson, 1986). Based on the water quality criteria presented in Annex A, an index value of 20 or less is

considered excellent water. The lower part of the Toms River has been given a water quality index rating of 9. Water quality trends at a monitoring station in the lower Toms River have shown an increase in stream temperature, pH and total Kjeldahl nitrogen, and a decrease in total mercury from 1977 to 1985. Other parameters, i.e., dissolved oxygen, biochemical oxygen demand, fecal coliform, total dissolved solids, phosphorous and lead, have shown no distinct change during this period (Robinson, 1986).

2.2 Groundwater Hydrology

Several features of the hydrogeology are described here to characterize the BOMARC Missile Site. Both the unsaturated zone and the principle aquifers located beneath the site are described. The local groundwater monitoring network, groundwater flow characteristics, and groundwater quality are also described. Last, an inventory of groundwater use is provided for the BOMARC area.

2.2.1 Aquifer Formations

The New Jersey Coastal Plain consists of a seaward-dipping wedge of unconsolidated sediments, including sand, silt, clay, and gravel. The unconsolidated sediments have formed a vertical sequence of sandy aquifers with intervening confining layers of silt and clay. The principal aquifers located beneath the BOMARC Missile Site are, in descending order, the Cohansey-Kirkwood, Vincentown, Wenonah-Mount Laurel, Englishtown and Potomac-Raritan-Magothy formations (Battelle, 1988a). The uppermost Cohansey-Kirkwood and lowermost Potomac-Raritan-Magothy formations are the highest yielding and the most important of the aquifers in the site area due to the available saturated thickness, and the location and area available for recharge. The eastward-dipping Cohansey-Kirkwood aquifer outcrops at McGuire AFB and the BOMARC Missile Site, and receives direct recharge from precipitation. Additionally, water stored in the wetlands of the Pinelands region provides a large surface source which may represent induced vertical recharge due to pumping stress on the aquifer. The Potomac-Raritan-Magothy aquifer is thick and receives significant recharge from its surficial outcrop area along the Delaware River. The aquifer is overlain by a thick clay confining layer which acts as a hydraulic barrier between the Potomac-Raritan-Magothy and the overlying Wenonah-Mount Laurel and Englishtown aquifers. These aquifers, in turn, are overlain by confining sediments which limit the hydraulic connection with the shallow Cohansey-Kirkwood aquifer (Rhodehamel, 1970).

The Cohansey-Kirkwood Formation is the primary aquifer of interest at the BOMARC Missile Site because it is the first groundwater system encountered beneath the site. It is believed to be hydraulically separated from deeper aquifers by confining layers. Recharge into the surficial aquifer has been interpreted to enter the ground and flow principally in the upper portion of the Cohansey Sand, with lesser flow going deeper into the underlying Kirkwood Sand. The Cohansey Sand is coarse and facilitates rapid, shallow flow of groundwater from recharge areas to discharge areas. The Kirkwood Sand consists of fine to medium grain size and increases in silt and clay content to the southeast toward the Atlantic coast. The higher fines content in lateral and vertical directions of the unit tend to limit the deep penetration of recharge water into the groundwater flow system, and favor movement through the shallow flow system of the

Cohansey (Rhodelhamel, 1970). Therefore, the evaluation of aquifer characteristics presented here focuses on the Cohansey sand.

The Cohansey Sand ranges in thickness from a few feet in outcrops to the north and west, to approximately 250 feet to the south and east in the downdip direction. The average thickness is about 1,000 feet. The combined thickness of the Cohansey-Kirkwood Formation in the area of the BOMARC Missile Site is interpreted to be between 50 and 100 feet. Explorations completed at the site show coarse, medium and fine sands to a depth of more than 60 feet below the ground surface. Several lenses of silt and clay were encountered in site borings within these sandy formations.

The hydraulic properties of the Cohansey aquifer indicate that it can supply large quantities of groundwater. The saturated thickness of the Cohansey aquifer averages about 100 feet, the transmissivity is estimated to range from 75,000 to 100,000 gallons per day (gpd) per foot, and the hydraulic conductivity is from 750 to 1,000 gpd per square foot (Rhodehamel 1970). Pumping wells completed in the aquifer can potentially yield 500 to 1,000 gallons per minute. Thinner portions of the aquifer would result in a lower transmissivity value and yield. The average specific yield of the Cohansey Sand has been reported as 21 (Battelle, 1988) and 23 (Rhodehamel, 1970) percent.

2.2.2 Unsaturated Zone

The thickness of the unsaturated zone beneath the BOMARC Missile Site varies from about 20 to 55 feet. Native sediments in the unsaturated zone consist primarily of stratified sands with lenses of silt and clay. Near the top of the water table, peat and organic silt have been observed in several boring explorations completed at the site. The clean sands of the Cohansey are estimated to have a porosity of 38 percent with an average water retention capacity of 15 percent (Rhodehamel, 1970). The porous nature of the sands allows recharge water to move rapidly downward to the water table. The significant effects of silt/clay lenses within the sand are: (1) a slowing of vertical seepage, (2) increased retention of water, and (3) localized build-up of water saturation in a perched condition. Explorations at the site have shown evidence of perched water. However, the continuity of the silt/clay lenses and the presence and extent of perched groundwater are unknown.

2.2.3 Monitoring Network

The monitoring network available at the site consists of 22 groundwater monitoring wells installed in the upper Cohansey Sand and two inactive water supply wells screened in the Kirkwood Sand. The monitoring wells are screened to a depth of 15 to 20 feet below the water table. The water supply wells are completed to a depth of 100 feet below ground surface (Battelle, 1988) and are reported to range from 52 to 125 feet deep (USAFOEHL, 1986). The network of wells is available for continued groundwater monitoring at the site. Groundwater monitoring well data are provided as Table 2-1. Individual private wells may exist in the region near the site, however, additional research and/or survey work is needed to confirm the existence and use of all wells in the area.

Table 2-1
Groundwater Monitoring Well Data

Well I.D. No.	Elev. Ref.[1] (ft above MSL)	Total Depth[1] (ft)	Water Level Measures: Depth to Top of Screen[1,2]	1987[3]	1990[4]
MW-16	155.92	38	23	129.38	---
MW-17	153.66	31	16	129.49	---
MW-41	159.87	44	29	129.31	---
M2-42	156.69	40	25	128.86	---
MW-43	155.47	44	29	128.91	---
MW-44	152.01	40	25	129.18	---
MW-45	150.54	40	25	129.25	---
MW-46	149.93	40	25	129.16	---
MW-47	169.62	55	40	128.93	128.47
MW-48	145.73	34	19	127.63	126.83
MW-49	167.10	55	40	128.62	128.00
MW-BMC-1	144.73	30	15	129.39	---
MW-BMC-2	153.74	40	25	128.43	---
MW-BMC-3	143.14	30	15	129.09	---
MW-BMC-4	140.08	30	15	128.14	---
PU-1	182.89	67	52	128.49	128.04
PU-2	174.31	57	42	129.01	128.65
PU-3	177.06	62	47	128.96	128.39
PU-4	177.67	60.5	45.5	129.87	129.54
PU-5	169.01	52.25	37.25	129.21	128.67
PU-6	1683.27	50	35	129.17	128.72
PU-7	152.30	40	25	127.40	127.1

[1] Elevation reference; MSL = mean sea level; from Weston (1989).
[2] All screened intervals are 15 feet.
[3] From Weston (1989) water levels measured 3/10/87 (wells MW) and 7/7/87 (wells PU at the top of water column).
[4] From The Earth Technology Corporation (1991), water levels measured July, 1989.

2.2.4 Flow Net Characteristics

Beneath the area of the BOMARC Missile Site, the Cohansey-Kirkwood Formation is an unconfined, water table aquifer. Further to the south and east, the formation dips beneath a layer of sediments with higher silt and clay content and becomes a confined aquifer system. The deeper permeable formations located beneath the Cohansey-Kirkwood Sands are separated by confining layers which limit flow between aquifer systems, however, heavy local pumping stresses may induce vertical leakage. Water level data for each aquifer system would serve to quantify the amount and significance of vertical leakage, if any, in the area of the site.

The Kirkwood Sands are separated by confining layers which limit flow between aquifer systems; however, heavy local pumping stresses may induce vertical leakage. Water level data

for each aquifer system would serve to quantify the amount and significance of vertical leakage, if any, in the area of the site.

Water level data at some monitoring wells reportedly have shown upward seepage gradients, indicating that groundwater in deeper regions of the Cohansey-Kirkwood aquifer moves upward toward the land surface. Rhodehamel (1970) has presented an interpretation of an idealized flow system in the Cohansey-Kirkwood Formation of the Pinelands region as shown in Figure 2-2. Local recharge to groundwater is depicted as moving along shallow flow paths and discharging to nearby surface water courses. Deeper movement into the Cohansey and Kirkwood formations is believed to be limited by a decrease in aquifer transmissivity at depth, and in the southeast direction of formation dip. In summary, the geologic setting favors local flow systems. Additional site-specific data are required to provide a detailed three-dimensional understanding of the groundwater flow systems beneath the BOMARC Missile Site.

Water level data (Weston, 1988) have been used to interpret groundwater flow directions for water table conditions in the Cohansey Sand (see Figure 2-3). The data suggest a north-south trending groundwater divide exists immediately to the east of the Ocean County Highway No. 539. From the divide, groundwater flows to the east-northeast and to the west-southwest. In both directions, the Elisha Branch is the nearest surface water receptor for the discharge of groundwater that originates as precipitation at the BOMARC Missile Site. Groundwater movement to the north is not expected, although water level data are not available to verify this condition. On the basis of available topographic maps, the groundwater divide appears to be shifted to the west, i.e., it does not coincide with the surface water divide. The apparent shift in the divide may be due to: (1) the lack of infiltration over the paved launch area, and (2) diversion of surface runoff into the drainage ditch at the west end of the launch area. As a result, infiltration may be enhanced by the additional runoff along unpaved portions of the drainage ditch.

Site-specific water level data are not available for the deeper portions of the Cohansey-Kirkwood aquifer to more completely characterize vertical groundwater movement beneath the site. However, if the idealized flow system described in Figure 2-2 applies to the BOMARC Missile Site, deeper regional groundwater flow is expected to be to the east, toward the Elisha Branch, and the nearest downstream surface water courses.

Site-specific hydraulic conductivity data are needed for the Cohansey aquifer at the BOMARC Missile Site to characterize groundwater flow rates. However, on the basis of hydraulic conductivity estimates derived by Weston (1988) from general numbers provided in Todd (1980) of 100 feet per day, the horizontal groundwater flow rate was estimated to range from 0.5 to 1.2 feet per day. The calculations further assumed an effective porosity of 0.3 and a water table hydraulic gradient (i) varying from 0.0016 to 0.0037 foot per foot. The horizontal distance from Shelter 204 to Elisha Branch along the southwest groundwater flow path is approximately 2,000 feet. The horizontal distance from the shelter to Elisha Branch along the northeast groundwater flow path is approximately 4,000 feet. Using an average horizontal groundwater flow rate of 1.2 feet per day ($i=0.0037$ ft per ft) along the southwest flow path, and 0.5 foot per day ($i=0.0016$ ft per ft) along the northeast flow path, the estimated travel time for groundwater flow from the shelter to Elisha Branch ranges from 5 to 22 years.

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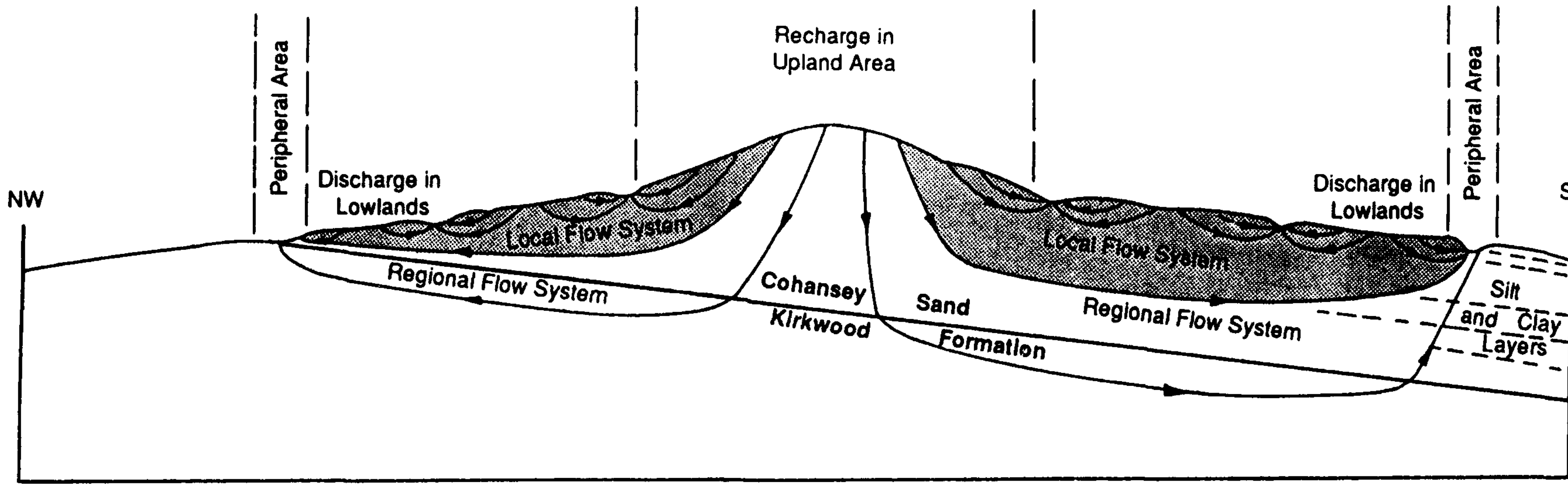

LEGEND

Groundwater Flow Pattern

VERTICALLY EXAGGERATED

Source: Rhodehamel, 1970.

FIGURE 2-2

GROUNDWATER FLOW SCHEMATIC, PINELANDS REGION

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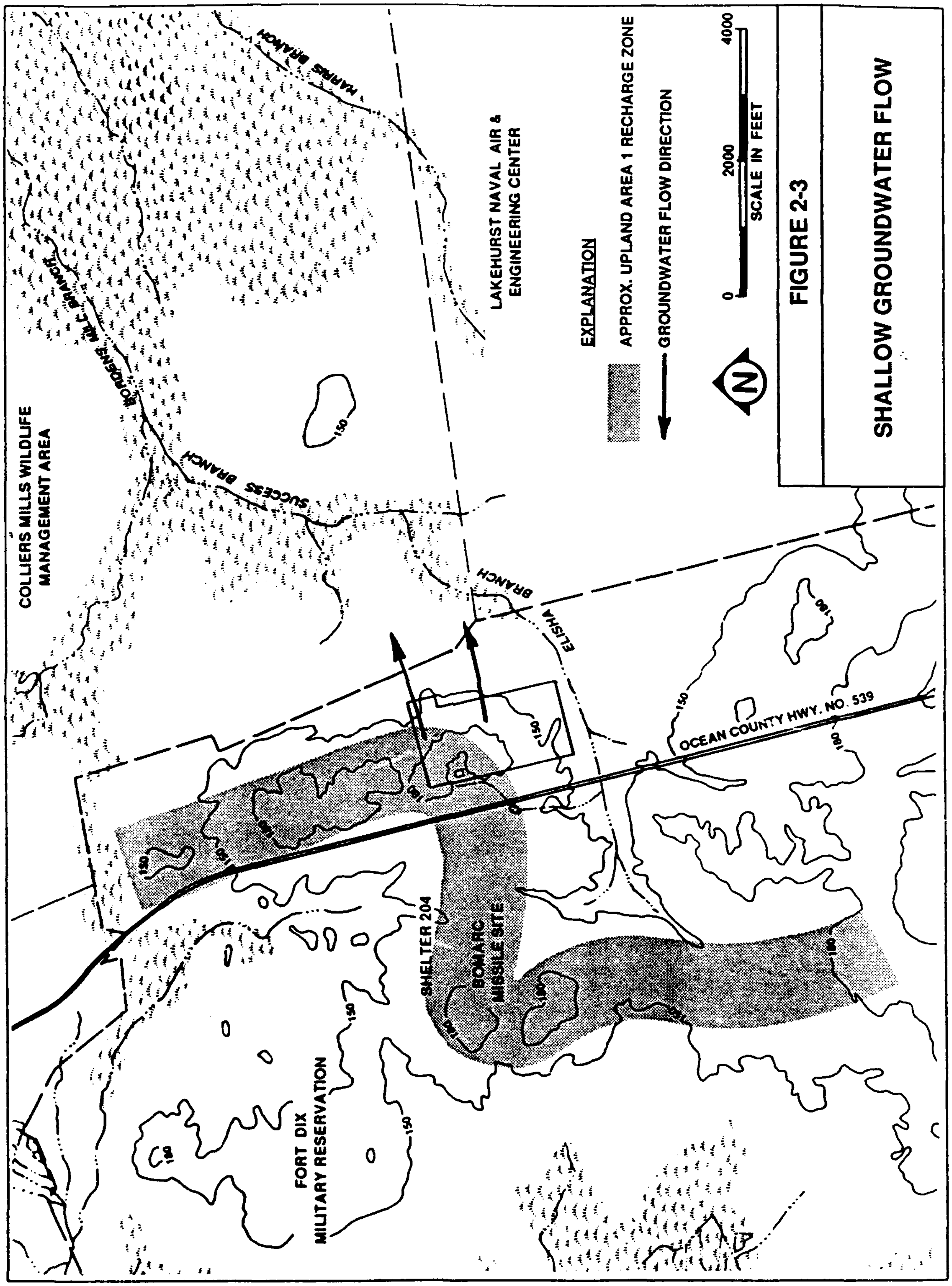

FIGURE 2-3

SHALLOW GROUNDWATER FLOW

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2.2.5 Water Quality

Limited groundwater quality information is available for the BOMARC Missile Site. The data collected at the site has focused on site-derived contamination (USAFOEHL, 1986; Weston, 1988). Weston (1988) has indicated that volatile organic chemicals and plutonium were detected at several monitoring well locations. Plutonium was detected in monitoring wells located to the northeast (PU-7), west (PU-2), and immediately to the north (PU-3) of Shelter 204. There is some concern that this plutonium originated in the surface sediments and contaminated the groundwater during well construction. This is supported by the fact that subsequent groundwater sampling in these wells has not shown elevated plutonium levels. Analyses for plutonium in groundwater samples from wells located outside the site boundaries have shown no contamination (USAFOEHL, 1986).

Standard water supply parameters (i.e., inorganic species and others) have not been evaluated at the site. However, water quality data are available from past studies of regional conditions. The Pinelands groundwater quality is known to be acidic and contains dissolved iron (similar to the surface waters). The pH ranges from 3.5 to 5.5 (Means, *et al.*, 1981). Total dissolved solids range from 25 to 100 ppm, which is higher than surface water, and is believed to be due primarily to iron, aluminum and other trace elements. Groundwater hardness is soft to moderately hard, generally showing less than 40 ppm. Other maximum and minimum concentrations of chemical constituents and physicochemical properties of groundwater in the Pinelands region are presented in Annex A.

2.2.6 User Inventory

Large quantities of groundwater exist in the Cohansey-Kirkwood aquifer system. The resource is relatively undeveloped in the interior of the coastal plain, but is heavily utilized near the coast in the Atlantic City region.

The BOMARC Missile Site is located within the area supplied by the Lakehurst Naval Air Station Water System. A few other private, industrial and agricultural groundwater users exist within the region (Battelle, 1988). The USAFOEHL (1986) study identified several private residence wells within one to three miles of the site.

3.0 DATA SOURCE IDENTIFICATION

Data sources include existing technical literature supplemented with several site-specific studies to be carried out at the BOMARC Missile Site. The technical literature is more general in nature, covering regions larger than the site.

3.1 Existing Technical Literature

The following list of existing technical literature identifies sources related to the geology, surface water hydrology, groundwater hydrology and geochemistry of the New Jersey coastal plain in the vicinity of the BOMARC Missile Site. These resources have been used in the development of this report. In addition, discussion and correspondence have taken place with persons in state

and federal agencies, and private consulting companies who have knowledge and experience relating to the hydrology of the New Jersey Coastal Plain.

- Means, J.L., Yuretich, R.F., Crerar, D.A., Kinsman, D.J.J., and Borcsik, M.P., 1981. Hydrogeochemistry of the New Jersey Pine Barrens, Bulletin 76, State of New Jersey Department of Environmental Protection and Energy and the New Jersey Geological Survey, 107 p.

- New Jersey Department of Environmental Protection and Energy, Division of Water Resources, 1983. Radioactive Mineral Occurrences in New Jersey, Open File Report No. 83-5, 19 p.

- New Jersey Department of Environmental Protection and Energy, Division of Water Resources, 1986. State Water Quality Inventory Report.

- New Jersey Department of Environmental Protection and Energy, Division of Water Resources, 1980. Summary of Consultant's Findings for the New Jersey Statewide Water Supply Plan.

- New Jersey Department of Environmental Protection and Energy, 1979. New Jersey State Water Supply Master Plan, Task 7, Watershed Resource Management Activities, Subtask 7C, Ground-water Management, 178 p.

- Rodehamel, E.G., 1970. A Hydrologic Analysis of the New Jersey Pine Barrens Region, State of New Jersey Department of Environmental Protection and Energy, Water Resources Circular No. 22, 35 p.

- Tiner, R.W., Jr., 1984. Atlas of National Wetlands Inventory Maps for New Jersey, U.S. Department of the Interior, Fish and Wildlife Service.

- United States Geological Survey (USGS) 7.5 minute topographic map series, Cassville, Lakehurst, Whiting, Keswick Grove, Adelphia, Roosevelt, Allentown, Browns Mills and New Egypt quadrangles.

- Walker, R.L., 1983. Evaluation of Water Levels in Major Aquifers of the New Jersey Coastal Plain, 1978, U.S. Geological Survey, Water Resources Investigations Report 82-4077, 56 p. with plates.

- Zapecaza, O.S., 1984. Hydrogeologic Framework of the New Jersey Coastal Plain, U.S. Geological Survey Open File Report 84-730, 61 p. with plates.

3.2 Site Specific Studies

A number of site-specific environmental studies have been carried out at the BOMARC Missile Site at McGuire AFB. The goals of these studies have been to characterize the geologic and environmental setting at the BOMARC Missile Site and to assess the existence, concentration and extent of any surface and subsurface radioactive contamination that might exist at the site.

The following is a listing of site-specific reports of studies that have been conducted at the BOMARC Missile Site and which have been used in the development of this appendix. It should be noted that a compilation and data summary of additional earlier studies at the site are included in the draft Work Plan for the RI/FS program.

- Battelle Columbus Division, December 9, 1988. Draft Work Plan, Installation Restoration Program, Stage 2, BOMARC Missile Site, McGuire AFB, NJ.

- Battelle Columbus Division, December 9, 1988. Quality Assurance Project Plan, Draft Report, Installation Restoration Program, Stage 2, BOMARC Missile Site, McGuire AFB, NJ.

- Core Boring Data and Test Pit, January 20, 1958. McGuire Special Facility (BOMARC Missile Site), developed by Wigton-Abbott Corp., Newark, NJ and Office of District Engineer, U.S. Army Engineer District, Philadelphia, PA, Drawing No. AW 16-14-01.

- Roy F. Weston, Inc., January, 1988. Installation Restoration Program, Phase II - Confirmation/Quantification Stage 2, Volume 1, Draft Report, McGuire AFB, NJ.

- The Earth Technology Corporation, January, 1991. Installation Restoration Program, Draft RI/FS Report, BOMARC Missile Site, McGuire AFB, NJ.

4.0 METHODS FOR ASSESSING EXISTING BASELINE CONDITIONS

Assessment of baseline conditions for surface water and groundwater within the Region of Influence (ROI) involved: (1) the acquisition of physical and chemical data for both surface water and groundwater, and (2) interpretive evaluation of the data to characterize the surface water and groundwater regimes and their interaction.

The following types of physical and chemical data from the hydrologic systems were acquired for the EIS for the type of evaluation described:

- Water Level Data from Monitoring Wells - The elevation of the surface of the groundwater table was gathered from the historical record and measured in monitoring wells. These measurements, with the hydraulic conductivity and effective porosity, were used to estimate the direction and rate of groundwater flow. Measurements were recorded to attempt to evaluate the groundwater flow characteristics.

- Water Quality Measurements of Surface Water and Groundwater - Existing water quality data were collected on the groundwater monitoring wells, water supply wells and surface water drainageways in the area of the BOMARC Missile Site. Field and laboratory analyses were conducted to determine the concentration of selected inorganic and organic chemical parameters, including plutonium, americium, and other radioactive species, as appropriate.

- Topographic Mapping of Site and Vicinity - The analysis of hydrologic systems requires elevation data for all features that have influence on surface water flow and groundwater levels, including surface water and stream channel features, and contaminant source areas. The best available topographic map and survey data was collected and compiled for the BOMARC Missile Site and vicinity.

- Watershed limits were estimated, drainage areas were measured, and drainage pathways were identified for the BOMARC Missile Site and vicinity. Existing information was gathered on watersheds in the region, including drainage areas, average flow conditions, and extreme flow conditions.

5.0 METHODS FOR ASSESSING HYDROLOGIC IMPACTS

The potential short-term and long-term hydrologic impact from radionuclide contamination within the ROI was determined on the basis of the following factors:

1. The capability of surface water and groundwater pathways to transport radionuclide contaminants from the BOMARC Missile Site.

2. The degree and extent of radionuclide contamination in surface water and groundwater.

3. The location and type of human and environmental receptors that are present within the hydrologic ROI.

4. The exposure duration and intensity on receptors from contaminants present in surface and groundwater.

5.1 Contaminant Transport Pathways

The current surface and groundwater flow and contaminant transport pathways in the vicinity of the BOMARC Missile Site were identified with the available technical data for the site and vicinity, supplemented by field data that were collected as part of the RI/FS program. The portions of the field data that are specific to the determination of hydrologic flow pathways are site reconnaissance (including geologic mapping), soil borings and water level measurements. The array of data collection points, particularly the monitoring wells, was utilized such that a three-dimensional evaluation of flow pathways could be made. A number of water level readings were made during the course of the RI/FS in order to estimate the seasonal water level variations and flow pathway change.

5.2 Water Quality

Evaluation of water quality required surface water and groundwater sampling and analysis. The principal chemical species of interest are plutonium and americium. As part of the RI/FS for the BOMARC Missile Site, surface water and groundwater samples were collected from an array of sampling points in streams and monitoring wells. Chemical data from the source

characterization effort in the RI/FS were used to evaluate the water quality in the hydrologic system, and the extent of contaminant transport.

5.3 Identification of Receptors

Existing and potential human and environmental receptors were identified on the basis of their proximity to contaminant transport pathways. The hydrology assessments depicted the current and potential future surface and groundwater flow regimes at the site, and the ultimate fate of surface and groundwater emanating from the site. Existing and potential human and environmental receptors are identified in the Biology Methodology Development Report (Appendix 3). Potential receptors may be located within or near the hydrologic systems or have the potential to be affected by contaminant transport within the systems, including water supply wells that derive all or a portion of their water supply from sources, that are hydrologically connected to the BOMARC Missile Site.

5.4 Exposure Assessment

It should be noted that the principal routes of entry of plutonium and americium into the body are via inhalation, ingestion, or contact. The latter routes are liable to occur if a human receptor is in contact with a contaminated water course. Inhalation of the radionuclides has a potential to occur where intermittent surface water courses or groundwater discharge zones distribute contaminants in areas that are intermittently dry.

5.5 Risk Assessment

The impact of hydrologic flow and contaminants on human and environmental receptors was evaluated by means of a risk assessment as described in the Draft Guidance for Conducting Remedial Investigations and Feasibility Studies Under Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (USEPA, 1988).

6.0 LEVELS OF IMPACT CRITERIA

Level of impact (LOI) criteria for the hydrologic assessment are established to address the principle contaminant, plutonium. The LOI for surface water and groundwater at the BOMARC Missile Site is tied directly to the National Primary Drinking Water Regulations (40 Code of Federal Regulations (CFR) 141). Therefore, the LOI are focused, specific, and are presented in quantitative terms.

In determining the LOI, it is assumed that ^{239}Pu, an alpha particle emitter, is the principal radionuclide that is present on the BOMARC Missile Site. Radiological surveys conducted at the site by the United States Air Force Occupational and Environmental Health Laboratory (USAFOEHL) support this assumption (USAFOEHL, 1986). The maximum contaminant level (MCL) standard for gross alpha concentration is 15 pCi per L as set in 40 CFR 141. Radionuclides present on the BOMARC Missile Site also emit beta and gamma radiation. Beta and gamma radiation are insignificant compared to alpha radiation, with respect to health impacts and level of radioactivity emitted by the site contaminants. The standards for beta and gamma activity are based on the concentration of a radionuclide causing four mrem total body or organ

dose equivalents calculated on the basis of a two liter per day drinking water intake. These standards result in a criteria that is greater than 15 pCi per L, therefore the more stringent 15 pCi per L standard has been utilized in the development of LOIs. In previous studies at the site, gross alpha activity has been measured by evaporating a 200 ml sample and counting the residue with a windowless gas-flow proportional counter.

- Negligible Impact - Gross alpha concentrations due to ^{239}Pu in the surface water or groundwater are significantly lower than the MCL or no receptors at risk. Surface and groundwater flow regimes are not altered. No mitigation is required.

- Low Impact - Gross alpha concentrations due to ^{239}Pu in the surface water or groundwater are less than or equal to the MCL and some receptors may be at risk. Surface and groundwater flow regimes are slightly altered. Mitigation may be required in some areas to lower risk. to acceptable levels.

- Moderate Impact - Gross alpha concentrations due to ^{239}Pu in the surface water or groundwater are equal to or slightly greater than the MCL, and human and environmental receptors are likely to be at risk. Surface and groundwater flow regimes are moderately altered. Mitigation measures will be required.

- High Impact - Gross alpha concentrations due to ^{239}Pu in surface water or ground water are equal to or greater than the MCL, and human and environmental receptors are likely to be at great risk. Surface and groundwater flow regimes are severely altered. Immediate mitigative action required.

7.0 SIGNIFICANCE CRITERIA

The significance of an impact is determined by evaluating its context and intensity as required under the Council on Environmental Quality (CEQ) regulations (40 CFR 1508.27). According to the CEQ regulations, the following items should be considered in evaluating the significance of an impact, and applied to beneficial as well as adverse impacts as they concern hydrologic processes or resources.

- effect on public health and safety
- unique (e.g., historic, scenic, etc.) features of the area
- effects on the environment that are likely to be controversial
- effects on the environment that are uncertain or unknown
- action that establishes a precedent with significant effects
- action that contributes to significant cumulative impact
- adverse effect on scientific, cultural or historic places
- adverse effect on an endangered species
- action that threatens a violation of Federal, state or local law.

8.0 REFERENCES

Battelle Columbus Division, December 9, 1988a. Draft Work Plan, Installation Restoration Program, Stage 2, BOMARC Missile Site, McGuire AFB, NJ.

Battelle Columbus Division, December 9, 1988b. Quality Assurance Project Plan, Draft Report, Installation Restoration Program, Stage 2, BOMARC Missile Site, McGuire AFB, NJ.

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Robinson, 1986. New Jersey 1986 State Water Quality Inventory Report, N.J. Department of Environmental Protection, Division of Water Resources, Bureau of Water Resource Management Planning, Trenton, N.J.

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USAFOEHL, Human Systems Division. 1988 Results of the 1987 Radiological Survey of the Fort Dix B MARC Missile Site, New Jersey - Final Report. Brooks Air Force Base, Texas.

USEPA, 1988, Draft Guidance for Conducting Remedial Investigation and Feasibility Studies Under CERCLA

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Annex A

Water Quality Data

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Table A-1
Physicochemical Properties of Pine Barrens Region Water[a]

	Surface Water			Ground Water		
	Minimum	Maximum	More Common Extreme Value[c]	Minimum	Maximum	More Common Extreme Value[c]
Period of Collection		**Circa 1920-1925 to 1967**			**Circa 1951 to 1967**	
Silica (SiO_2)	0.14	17.00	—	1.10	42.00[b]	10.0
Aluminum (Al)	.0	.6	—	.00	10[b]	1.8
Iron (Fe)	.00	7.1	—	.00	49[b]	.5-11.0
Manganese (Mn)	.00	.77	—	.00	2	—
Calcium (Ca)	.0	26	—	.0	90[b]	10
Magnesium (Mg)	.0	7.8	—	.0	18[b]	4.4
Sodium (Na)	.4	28	—	.9	26[b]	5.7
Potassium (K)	.0	7	—	.0	6.2[b]	4
Lithium (Li)	—	Trace	—	—	.4	
Bicarbonate (HCO_3)	.0	72[b]	10	.0	146[b]	10
Carbonate (CO_3)	—	.0	—	—	.0	—
Sulfate (SO_4)	.8	85	—	.0	45[b]	15
Chloride (Cl)	.0	60[b]	8	1.8	34[b]	7
Fluoride (F)	.0	1	—	.0	4[b]	.3
Nitrate (NO_3)	.0	8.9	—	.0	37[b]	7
Phosphate (PO_4)	.00	.51	—	—	.0	—
Boron (B)	Trace	.10	—	.00	.14	—
Carbon Dioxide (CO_2)	.00	.02	—	2.2	25	—
Dissolved Solids						
Calculated	—	—	—	—	—	—
Residue on Evaporation at 180°C	17	195[b]	50	13	135[b]	35
Hardness as $CaCO_3$	2	78[b]	25	.0	70[b]	13
Noncarbonate Hardness as $CaCO_3$	.0	71[b]	15	.0	52[b]	18
Alkalinity as $CaCO_3$	—	—	—	—	—	—
Total Acidity as H^{+1}	.1	.4	—	.0	.6	—
Specific Conductance (micromhos/cm at 25°C)	24	364[b]	90	15	315[b]	45
pH (standard units)	3.8	8.0[b]	7	4.2	7.3[b]	5.8
Color	.0	450[b]	3-100	1	1,300[b]	10
Temperature (°C)	0	30[b]	24	9	21[b]	14
Dissolved Oxygen (D.O.)	4.2	10.3	—	—	—	—
Suspended Sediment (in tons/day/mi²)	.001	.24	—	—	—	—

[a] Concentrations are reported in milligrams per liter (mg/l); other properties are reported in units shown in the left column. Table based upon about 7,000-10,000 separate quality of water determinations.

[b] These values are considered to be atypical for the region and are thought to be influenced by man's activities such as farming, waste disposal, and manufacturing.

[c] Values in these columns are interpreted as being more indicative of the upper and where a range is given of lower and upper values existing in the natural environment.

Source: Rhodehamel, 1970.

Table A-2
Water Quality Index Categories, Components, and Criteria for Assessing New Jersey's Rivers and Streams

Category	Component	Criteria (Index Value of 20)
Temperature	Temp. Cold-water fishery	19 C
	Temp. Warm-water fishery	28 C
Oxygen	Dissolved Oxygen-Trout Production	7 mg/l
	Dissolved Oxygen-Trout Maintenance	5 mg/l
	Dissolved Oxygen-Nontrout	4 mg/l
	Dissolved Oxygen Saturation	80, 120 percent
pH	pH-Non-acidic waters	6.5 8.5 SU
	pH-Pinelands naturally acidic	3.5 - 5.5 SU
	pH-Non-Pinelands naturally acidic	4.5 - 7.5 SU
Bacteria	Fecal Coliform	200 MPN/100ml
	Total Coliform	2400 MPN/100ml
Nutrients	Total Phosphoros-Free flowing waters	0.10 mg/l
	Total Phosphoros-Above impoundment	0.05 mg/l
	Total Kjeldahl Nitrogen	2.5 mg/l
	Total Inorganic Nitrogen	2.0 mg/l
Solids	Total Dissolved Solids	500 mg/l
	Conductivity	750 micromho/cm
Ammonia	Un-ionized-Warm waters	0.05 mg/l
	Un-ionized-Trout waters	0.02 mg/l
Metals	Total Lead	50 μg/l
	Total Copper	50 μg/l
	Total Mercury	0.50 μg/l
	Total Cadmium	4.0 μg/l
	Total Chromium	50 μg/l

Source: Robinson, 1986.

Appendix 3-3

Meteorology/Air Quality Methodology Development Report

May 1992

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TABLE OF CONTENTS

LIST OF TABLES

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1.0 INTRODUCTION

This document was prepared to support the analysis provided in the Environmental Impact Statement (EIS). The objective of this document is to supplement the EIS by providing the reader with information to augment and support the analysis provided in the EIS.

2.0 AIR QUALITY RESOURCE DESCRIPTION

The climatology, dispersion meteorology, and air quality of the area are described in Section 3.4 of the EIS. Detailed regional climatic data are provided in Annex A to this Appendix.

3.0 DATA SOURCE IDENTIFICATION

In the following section, data sources for climatological, meteorological and air quality data are identified.

3.1 Climatological and Meteorological Data

Monthly, seasonal, and annual joint frequency distributions of wind speed, direction and atmospheric stability were obtained for McGuire Air Force Base (AFB) and Lakehurst Naval Engineering and Aeronautic Center (NAEC), from the National Climatic Data Center. Local climatic information, including the average and extreme duration and intensity of precipitation events, and average and extreme data on temperature, winds, etc. were also been obtained from the National Climatic Data Center. Data describing severe weather were derived from a number of sources including Ruffner and Bair (1977) and the National Climatic Data Center. Mixing depth information were derived from Holzworth (1972).

3.2 Air Quality Data

Information describing pollutant attainment status, ambient pollutant levels, and regional air pollutant sources were obtained from the New Jersey Department of Environmental Protection and Energy (NJDEPE).

4.0 METHODS FOR ASSESSING EXISTING BASELINE CONDITIONS

Baseline air quality was characterized through the use of data available from NJDEPE. No specific information was available regarding future baseline conditions. The NJDEPE has embarked on a program to reduce emissions of ozone precursors in an attempt to achieve air quality standards. This will also contribute to a reduction in emissions of nitrogen dioxide, carbon monoxide, lead, and particulate matter (NJDEPE, 1983). However, for the purposes of the EIS, it was assumed that the future baseline is identical to the present condition.

5.0 METHODS FOR ASSESSING AIR QUALITY IMPACTS

Impacts to air quality are anticipated to arise from activities that physically disturb the site and release particulates into the atmosphere, such as excavation of soils and sediments, building demolition, etc., or generate gaseous exhaust products (carbon monoxide, nitrogen and sulfur

oxides, and hydrocarbons) such as vehicles and heavy equipment. An assessment of the direct impacts of alternative implementation required a qualitative evaluation of the relative amounts of fugitive dust and gaseous exhaust associated with each alternative, and the duration of releases. Secondary impacts of the action, including impacts to air quality from traffic increases or increased vehicle miles, rerouting requirements, were also qualitatively assessed.

6.0 LEVELS OF IMPACT CRITERIA

The level of impact (LOI) represents the magnitude of the expected air quality degradation. The expected overall impacts on the air quality rescurce was categorized as negligible, low, moderate, or high. The criteria used for defining the LOIs were as follows:

- Negligible Impact--No impact is expected, or the impact is expected to be so small as to be essentially unnoticeable.
- Low Impact--The impact is noticeable, but consequences are not expected to significantly deteriorate the air quality condition, either short- or long-term.
- Moderate Impact--Air quality is adversely affected at least for the short-term. Long-term deterioration is not expected. Activities are not expected to contribute to an exceedance of any Ambient Air Quality Standard.
- High Impact--There is a substantial adverse effect on both the short-term and long-term air quality condition. Ambient Air Quality Standards may be exceeded.

There will be no impacts to climatology or dispersion meteorology.

7.0 SIGNIFICANCE CRITERIA

Because a qualitative approach was used in the assessment of air quality impacts, specific significance criteria cannot be addressed. Rather the alternatives were qualitatively discussed for their relative expected impacts to air quality, in terms of emissions levels and duration of impacts.

8.0 REFERENCES

Air Weather Service. Climatic Brief for McGuire AFB, 1942 through 1987. National Climatic Data Center, Asheville, North Carolina, 1988. 2 pp.

Holzworth, G.C. Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1972. 118 pp.

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Annex A

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Table A-1
Regional Climatic Data

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
Temperature (°F)													
Mean													
McGuire AFB	31	34	41	52	62	71	76	74	67	56	46	35	54
Lakehurst NAEC	32	33	41	51	61	70	75	73	66	56	46	36	53
Mean Max													
McGuire AFB	39	41	50	61	72	81	85	83	76	66	55	43	63
Lakehurst NAEC	40	42	50	61	71	80	85	83	76	66	55	44	63
Extreme Max													
McGuire AFB	74	74	87	93	94	99	102	100	100	88	82	75	102
Lakehurst NAEC	76	76	89	93	95	100	102	102	100	90	83	77	102
Mean Min													
McGuire AFB	24	25	32	41	51	61	66	65	57	47	37	28	44
Lakehurst NAEC	23	25	32	40	50	59	65	63	56	46	37	27	43
Extreme Min													
McGuire AFB	-8	-4	6	19	31	42	50	42	35	25	15	-1	-8
Lakehurst NAEC	-13	-7	3	20	30	40	49	40	30	17	14	2	-13

(Continued)

Table A-1
Regional Climatic Data
(Continued)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
Precipitation (Inches)													
Mean													
McGuire AFB	3.1	2.9	3.9	3.7	3.5	3.6	4.4	4.7	3.6	3.2	3.7	3.7	44.0
Lakehurst NAEC	3.3	3.1	3.8	3.3	3.3	3.4	4.0	4.5	3.4	3.2	3.6	3.9	42.8
Max													
McGuire AFB	9.2	5.7	7.5	8.2	9.2	8.3	10.2	15.0	9.4	6.9	8.8	7.6	15.0
Lakehurst NAEC	9.2	7.1	7.3	6.6	7.5	7.2	9.9	10.6	10.2	7.2	9.0	8.2	10.6
Min													
McGuire AFB	0.3	0.7	1.1	0.7	0.2	0.1	0.7	0.8	0.8	0.1	0.2	0.2	0.1
Lakehurst NAEC	0.5	1.1	0.5	0.9	0.3	#	1.0	0.9	0.6	0.2	0.4	0.5	#
24 Hr/Max													
McGuire AFB	2.2	2.4	2.3	3.7	2.9	4.1	4.7	9.6	4.2	3.3	3.4	2.7	9.6
Lakehurst NAEC	4.0	2.4	2.2	2.5	4.6	5.0	4.2	3.8	4.9	4.4	4.1	3.0	5.0

(Continued)

Table A-1
Regional Climatic Data
(Continued)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
Snowfall (Inches)													
Mean													
McGuire AFB	7	7	4	1	#	0	0	0	0	#	1	4	24
Lakehurst NAEC	6	6	6	#	#	#	0	0	0	#	1	4	23
Max													
McGuire AFB	18	27	27	9	#	0	0	0@	0	1	9	14	27
Lakehurst NAEC	22	27	35	4	#	#	0	0	0	#	7	19	35
24 Hr/Max													
McGuire AFB	15	18	20	6	#	0	0	0	0	1	9	8	20
Lakehurst NAEC	10	13	18	3	#	#	0	0	0	#	7	17	18
Relative Humidity (Percent)													
0700 LST													
McGuire AFB	70	71	71	72	74	75	80	81	81	79	76	74	75

(Continued)

Table A-1
Regional Climatic Data
(Continued)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
Snowfall (Inches) (Continued)													
0400 LST													
Lakehurst NAEC	77	74	75	76	86	93	91	92	91	85	81	81	84
Relative Humidity (Percent)													
1300 LST													
McGuire AFB	59	57	53	52	53	53	56	57	56	54	58	59	56
Lakehurst NAEC	61	55	54	47	53	55	54	58	59	55	58	60	56
Surface Wind													
Mean Wind Direction													
McGuire AFB	W	NW	N	$WN	$W	$S	$S	$S	$N	$W	$W	$WN	$W
Lakehurst NAEC	W	W	WN	W	W	W	W	W	W	W	W	W	W
Mean Wind Speed (Knots)													
McGuire AFB	7	7	7	7	5	5	4	4	4	5	6	7	6
Lakehurst NAEC	6	6	7	7	6	5	5	4	5	5	6	6	6

(Continued)

Table A-1
Regional Climatic Data
(Continued)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
Surface Wind (Continued)													
Instantaneous Peak Winds (Knots)													
McGuire AFB	49	53	54	56	62	71	68	70	66	76@	73	56	76
Lakehurst NAEC	58	63	76	60	60	62	55	71	51	75	71	54	76
Mean Cloud Amount (Tenths)													
McGuire AFB	7	6	6	7	7	6	6	7	6	6	7	7	6
Lakehurst NAEC	7	6	7	6	7	7	7	7	7	6	7	7	7
Mean Number of Days with:													
Precipitation >0.01 (Inches)													
McGuire AFB	11	9	11	11	11	10	9	9	8	8	10	10	117
Lakehurst NAEC	11	9	11	11	11	10	9	9	8	7	9	10	115
Precipitation >0.5 (Inches)													
McGuire AFB	2	2	3	3	2	2	3	3	2	2	3	3	30
Lakehurst NAEC	2	2	3	2	2	2	2	3	2	2	3	3	28

(Continued)

Table A-1
Regional Climatic Data
(Continued)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
Mean Number of Days with: (Continued)													
Snowfall >0.1 (Inches)													
McGuire AFB	4	3	2	#	0	0	0	0	0	#	#	2	11
Lakehurst NAEC	4	3	2	#	0	0	0	0	0	#	#	2	11
Snowfall > ..5 (Inches)													
McGuire AFB	2	1	1	#	0	0	0	0	0	0	#	1	5
Lakehurst NAEC	1	1	1	#	0	0	0	0	0	0	#	1	4
Thunderstorms													
McGuire AFB	#	#	1	2	4	5	7	6	2	1	1	#	29
Lakehurst NAEC	#	#	1	2	4	5	6	6	2	1	#	#	27

Notes:

Station Na.ne: McC··re AFB. NJ
Location: N40 01, W074 36
Hourly OBS Period of Record: August, 1977 to July, 1987
Summ·ary of Day Period of Record: September, 1942 to March, 1946
August, 1948 to July, 1987
Elevation· 133 feet

Legend

@ Based on less than full months
# Amount less than unit(s) given in heading
$ Percentage of calm winds greater than mean direction

Notes:

Station Name: Lakehurst, NJ
Location: N40 O2, W74 21
Period: February 1945 to December 1982
Elevation: 93 feet

Legend

Less than 0.5 days, 0.5 days or 0.05 inch, or 0.5 % as applicable. Hail was included in snowfall prior to January 1956 and after December 1979.

Source: Extracted from Air Weather Service, 1988, and Naval Oceanography Command Detachment, 1986.

Table A-2
Seasonal/Annual Distribution of Wind Speed and Direction
At McGuire AFB (1/66 to 12/70)

	Winter Wind Speed Class (knots)							Expected
	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	>21	Freq Ea Direction	Avg WS (knots)
N	0.02473	0.02220	0.02321	0.01365	0.00130	0.00046	0.08555	6.61970
NNE	0.01316	0.01180	0.01290	0.00817	0.00037	0.00019	0.04659	6.66785
NE	0.01235	0.01048	0.01319	0.00659	0.00028	0.00000	0.04289	6.46596
ENE	0.00588	0.00520	0.00613	0.00279	0.00046	0.00009	0.02055	6.60195
E	0.01209	0.00910	0.00947	0.00548	0.00046	0.00009	0.03669	6.24666
ESE	0.00880	0.00539	0.00223	0.00046	0.00000	0.00000	0.01688	3.86937
SE	0.00593	0.00353	0.00102	0.00019	0.00009	0.00000	0.01076	3.67007
SSE	0.01162	0.00538	0.00278	0.00056	0.00009	0.00000	0.02043	3.78023
S	0.02840	0.01626	0.00918	0.00120	0.00028	0.00019	0.05551	4.11439
SSW	0.02141	0.01412	0.00901	0.00186	0.00000	0.00000	0.04640	4.40539
SW	0.01976	0.01718	0.01217	0.00381	0.00056	0.00009	0.05357	5.29027
WSW	0.01965	0.01495	0.01801	0.01123	0.00158	0.00186	0.06728	7.24279
W	0.03171	0.03222	0.04810	0.04540	0.01235	0.00381	0.17359	9.01046
WNW	0.01804	0.02358	0.04689	0.03723	0.01151	0.00297	0.14022	9.57096
NW	0.01805	0.02275	0.02980	0.02451	0.00780	0.00306	0.10597	8.99094
NNW	0.01718	0.02098	0.02034	0.01597	0.00232	0.00037	0.07716	7.42425
Freq Ea WS Class	0.26876	0.23512	0.26443	0.17910	0.03945	0.01318	1.00004	7.33618

	Spring Wind Speed Class (knots)							Expected
	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	>21	Freq Ea Direction	Avg WS (knots)
N	0.02334	0.02219	0.02366	0.01182	0.00337	0.00064	0.08502	6.90790
NNE	0.01112	0.01082	0.01064	0.00473	0.00109	0.00036	0.03876	6.58269
NE	0.01083	0.01020	0.00727	0.00437	0.00118	0.00009	0.03394	6.26974
ENE	0.01251	0.01108	0.01118	0.00436	0.00073	0.00009	0.03995	6.11427
E	0.02237	0.02019	0.01883	0.00500	0.00045	0.00000	0.06684	5.54473
ESE	0.01174	0.01146	0.01091	0.00200	0.00000	0.00000	0.03611	5.39034
SE	0.00904	0.00946	0.00592	0.00073	0.00000	0.00000	0.02515	4.81252
SSE	0.01739	0.01409	0.01047	0.00145	0.00000	0.00000	0.04340	4.72592
S	0.04407	0.02837	0.02511	0.00527	0.00027	0.00009	0.10318	4.84595
SSW	0.02570	0.02046	0.01647	0.00473	0.00045	0.00000	0.06781	5.20941
SW	0.01801	0.01701	0.01637	0.00946	0.00154	0.00018	0.06257	6.59837
WSW	0.01379	0.01428	0.01902	0.01091	0.00109	0.00018	0.05927	7.19470
W	0.02257	0.02102	0.02830	0.02092	0.00445	0.00264	0.09990	8.15931
WNW	0.01391	0.01809	0.02729	0.02338	0.00427	0.00100	0.08794	8.71094
NW	0.01286	0.01656	0.02127	0.02292	0.00364	0.00164	0.07889	8.92515
NNW	0.01596	0.01501	0.02228	0.01438	0.00282	0.00073	0.07118	7.79798
Freq Ea WS Class	0.28521	0.26029	0.27499	0.14643	0.02535	0.00764	0.99991	6.72438

(Continued)

Table A-2
Seasonal/Annual Distribution of Wind Speed and Direction
At McGuire AFB (1/66 to 12/70)
(Continued)

	Summer Wind Speed Class (knots)							Expected
	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	>21	Freq Ea Direction	Avg WS (knots)
N	0.02268	0.01824	0.01225	0.00281	0.00000	0.00000	0.05598	4.77456
NNE	0.01383	0.01243	0.00880	0.00227	0.00000	0.00000	0.03733	5.04527
NE	0.01016	0.01052	0.00609	0.00145	0.00000	0.00000	0.02822	4.93196
ENE	0.01005	0.00771	0.00526	0.00091	0.00000	0.00000	0.02393	4.62265
E	0.01596	0.01487	0.00817	0.00027	0.00000	0.00000	0.03927	4.36415
ESE	0.01320	0.01043	0.00436	0.00009	0.00000	0.00000	0.02808	3.92539
SE	0.01840	0.01189	0.00345	0.00018	0.00000	0.00000	0.03392	3.50251
SSE	0.03375	0.02152	0.00698	0.00018	0.00000	0.00000	0.06243	3.52371
S	0.09119	0.05673	0.01980	0.00109	0.00000	0.00000	0.16881	3.57473
SSW	0.06222	0.04138	0.02069	0.00172	0.00009	0.00000	0.12610	3.97324
SW	0.04089	0.03457	0.02359	0.00345	0.00018	0.00000	0.10268	4.72044
WSW	0.02559	0.02333	0.01742	0.00382	0.00000	0.00000	0.07016	5.05523
W	0.02861	0.02832	0.01789	0.00236	0.00000	0.00000	0.07718	4.77378
WNW	0.01593	0.01634	0.01188	0.00172	0.00009	0.00000	0.04596	5.03710
NW	0.01382	0.01417	0.01317	0.00199	0.00018	0.00000	0.04333	5.39603
NNW	0.02313	0.01724	0.01352	0.00263	0.00000	0.00000	0.05652	4.80042
Freq Ea WS Class	0.43941	0.33969	0.19332	0.02694	0.00054	0.00000	0.99990	4.37517

	Fall Wind Speed Class (knots)							Expected
	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	>21	Freq Ea Direction	Avg WS (knots)
N	0.03032	0.01837	0.01589	0.00349	0.00009	0.00000	0.06816	4.71273
NNE	0.01654	0.01084	0.01020	0.00395	0.00037	0.00000	0.04190	5.39535
NE	0.01780	0.01084	0.00817	0.00220	0.00028	0.00018	0.03947	4.81492
ENE	0.01840	0.01102	0.00707	0.00220	0.00037	0.00018	0.03924	4.69432
E	0.02410	0.01692	0.00928	0.00037	0.00018	0.00000	0.05085	4.09135
ESE	0.01547	0.01112	0.00753	0.00101	0.00000	0.00000	0.03513	4.45332
SE	0.01575	0.00900	0.00597	0.00119	0.00009	0.00000	0.03200	4.28576
SSE	0.02302	0.01231	0.00625	0.00055	0.00009	0.00000	0.04222	3.75036
S	0.05663	0.02839	0.01075	0.00073	0.00009	0.00000	0.09659	3.41479
SSW	0.04648	0.02086	0.00956	0.00156	0.00000	0.00000	0.07846	3.52205
SW	0.02926	0.01636	0.01139	0.00193	0.00009	0.00009	0.059[illegible]2	4.27283
WSW	0.02535	0.01910	0.01342	0.00551	0.00018	0.00000	0.06356	5.11957
W	0.04818	0.03417	0.02996	0.01589	0.00165	0.00009	0.12994	5.74100
WNW	0.02169	0.02196	0.02765	0.01644	0.00248	0.00009	0.09031	7.18370
NW	0.02053	0.01425	0.01727	0.00974	0.00129	0.00009	0.06317	6.44578
NNW	0.02842	0.01433	0.01800	0.00836	0.00064	0.00018	0.06993	5.67682
Freq Ea WS Class	0.43794	0.26984	0.20836	0.07512	0.00789	0.00090	1.00005	4.96435

(Continued)

Table A-2
Seasonal/Annual Distribution of Wind Speed and Direction
At McGuire AFB (1/66 to 12/70)
(Continued)

	Annual Wind Speed Class (knots)							Expected
	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	>21	Freq Ea Direction	Avg WS (knots)
N	0.02534	0.02024	0.01873	0.00792	0.00119	0.00027	0.07369	5.90263
NNE	0.01363	0.01148	0.01062	0.00476	0.00046	0.00014	0.04109	5.95656
NE	0.01275	0.01050	0.00866	0.00364	0.00044	0.00007	0.03606	5.67263
ENE	0.01155	0.00877	0.00742	0.00257	0.00039	0.00009	0.03079	5.47873
E	0.01864	0.01530	0.01145	0.00277	0.00027	0.00002	0.04845	5.05325
ESE	0.01225	0.00961	0.00628	0.00090	0.00000	0.00000	0.02904	4.54390
SE	0.01213	0.00848	0.00409	0.00057	0.00005	0.00000	0.02532	4.10762
SSE	0.02141	0.01338	0.00664	0.00068	0.00005	0.00000	0.04216	3.92754
S	0.05519	0.03254	0.01626	0.00209	0.00016	0.00007	0.10631	3.92033
SSW	0.03874	0.02428	0.01397	0.00247	0.00014	0.00000	0.07960	4.19925
SW	0.02711	0.02133	0.01591	0.00468	0.00059	0.00009	0.06971	5.15392
WSW	0.02131	0.01793	0.01697	0.00786	0.00071	0.00050	0.06528	6.10386
W	0.03287	0.02891	0.03097	0.02103	0.00458	0.00163	0.11999	7.25398
WNW	0.01758	0.01996	0.02833	0.01961	0.00456	0.00101	0.09105	8.17803
NW	0.01653	0.01691	0.02034	0.01475	0.00321	0.00119	0.07293	7.86083
NNW	0.02105	0.01688	0.01853	0.01031	0.00144	0.00032	0.06853	6.54232
Freq Ea WS Class	0.35808	0.27650	0.23517	0.10661	0.01824	0.00540	1.00000	5.84476

Source: Extracted from National Climatic Data Center data files.

Table A-3
Seasonal/Annual Distribution of Wind Speed and Direction At Lakehurst NAEC (1/76 to 12/77)

	Winter Wind Speed Class (knots)							Expected
	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	>21	Freq Ea Direction	Avg WS (knots)
N	0.01232	0.00567	0.00845	0.00000	0.00000	0.00000	0.02644	4.48865
NNE	0.00969	0.01016	0.00459	0.00270	0.00000	0.00000	0.02713	5.18606
NE	0.01226	0.00468	0.00548	0.00000	0.00000	0.00000	0.02242	3.94245
ENE	0.00397	0.00926	0.00846	0.00090	0.00090	0.00000	0.02348	6.53173
E	0.01109	0.00567	0.00558	0.00000	0.00000	0.00000	0.02233	4.13597
ESE	0.00885	0.00628	0.00459	0.00000	0.00000	0.00000	0.01972	4.24379
SE	0.00824	0.00369	0.00298	0.00099	0.00000	0.00000	0.01589	4.37290
SSE	0.01696	0.00638	0.00836	0.00189	0.00090	0.00090	0.03538	5.49199
S	0.02825	0.01196	0.02320	0.01412	0.00099	0.00090	0.07942	6.70085
SSW	0.01656	0.01801	0.02268	0.00647	0.00000	0.00000	0.06372	6.19931
SW	0.01826	0.01035	0.01692	0.00586	0.00189	0.00000	0.05328	6.34426
WSW	0.01892	0.01871	0.01753	0.01799	0.00467	0.00099	0.07881	7.97308
W	0.05447	0.04141	0.06414	0.08954	0.03900	0.00836	0.29692	10.10707
WNW	0.02140	0.01455	0.03377	0.04647	0.01025	0.00179	0.12822	9.83088
NW	0.02478	0.01691	0.02338	0.01015	0.00369	0.00000	0.07891	6.68612
NNW	0.01075	0.00826	0.00807	0.00090	0.00000	0.00000	0.02798	4.93799
Freq Ea WS Class	0.27675	0.19194	0.25816	0.19799	0.06229	0.01294	1.00007	7.76142

	Spring Wind Speed Class (knots)							Expected
	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	>21	Freq Ea Direction	Avg WS (knots)
N	0.01365	0.01356	0.00359	0.00000	0.00000	0.00000	0.03080	3.85669
NNE	0.00572	0.00090	0.00368	0.00000	0.00000	0.00000	0.01030	4.30431
NE	0.00596	0.00550	0.00454	0.00000	0.00000	0.00000	0.01600	4.69077
ENE	0.00616	0.00547	0.01900	0.00179	0.00000	0.00000	0.03243	6.85562
E	0.00743	0.01801	0.02542	0.00541	0.00000	0.00000	0.05626	6.93593
ESE	0.01086	0.01715	0.00905	0.00179	0.00000	0.00000	0.03886	5.22956
SE	0.01051	0.01369	0.01544	0.00272	0.00000	0.00000	0.04236	5.95342
SSE	0.01368	0.01443	0.00989	0.00630	0.00000	0.00000	0.04430	5.90968
S	0.02268	0.03077	0.02253	0.01711	0.00179	0.00000	0.09488	6.79209
SSW	0.01024	0.00908	0.01619	0.00902	0.00179	0.00000	0.04633	7.64732
SW	0.01872	0.01548	0.01899	0.01443	0.00090	0.00000	0.06851	6.98728
WSW	0.01920	0.00917	0.02441	0.02079	0.00185	0.00000	0.07543	7.92832
W	0.02329	0.02542	0.04710	0.04254	0.01353	0.00720	0.15908	9.93805
WNW	0.02200	0.01820	0.02990	0.03187	0.00813	0.00448	0.11457	9.41987
NW	0.00840	0.01901	0.03712	0.03993	0.00726	0.00179	0.11351	10.10290
NNW	0.01817	0.01554	0.01192	0.01087	0.00000	0.00000	0.05651	6.24850
Freq Ea WS Class	0.21666	0.23137	0.29877	0.20458	0.03525	0.01347	1.00010	7.80247

(Continued)

Table A-3
Seasonal/Annual Distribution of Wind Speed and Direction
At Lakehurst NAEC (1/76 to 12/77)
(Continued)

	Summer Wind Speed Class (knots)							Expected
	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	>21	Freq Ea Direction	Avg WS (knots)
N	0.02315	0.01456	0.00362	0.00000	0.00000	0.00000	0.04134	3.34652
NNE	0.00497	0.00637	0.00090	0.00090	0.00000	0.00000	0.01313	4.49569
NE	0.00439	0.00362	0.00547	0.00000	0.00000	0.00000	0.01348	5.27948
ENE	0.01190	0.01098	0.00817	0.00000	0.00000	0.00000	0.03104	4.57983
E	0.00942	0.01537	0.01370	0.00365	0.00000	0.00000	0.04214	6.09144
ESE	0.01144	0.00909	0.00629	0.00000	0.00000	0.00000	0.02681	4.32776
SE	0.01626	0.01995	0.01005	0.00182	0.00000	0.00000	0.04808	4.87028
SSE	0.02459	0.01729	0.01539	0.00275	0.00000	0.00000	0.06002	4.85364
S	0.03810	0.03360	0.04011	0.01106	0.00000	0.00000	0.12286	5.82223
SSW	0.02208	0.02087	0.02281	0.00732	0.00000	0.00000	0.07308	5.88702
SW	0.03501	0.01889	0.02364	0.00275	0.00000	0.00000	0.08029	4.79571
WSW	0.02313	0.02711	0.02901	0.01184	0.00000	0.00000	0.09109	6.33059
W	0.03649	0.03523	0.04718	0.01910	0.00000	0.00000	0.13800	6.44728
WNW	0.02509	0.02718	0.02627	0.01732	0.00000	0.00000	0.09586	6.57869
NW	0.02157	0.02258	0.02729	0.00997	0.00000	0.00000	0.08141	6.28673
NNW	0.01234	0.00817	0.01830	0.00183	0.00000	0.00090	0.04153	6.32956
Freq Ea WS Class	0.31993	0.29085	0.29820	0.09030	0.00000	0.00090	1.00018	5.71024

	Fall Wind Speed Class (knots)							Expected
	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	>21	Freq Ea Direction	Avg WS (knots)
N	0.03061	0.00913	0.00270	0.00000	0.00000	0.00000	0.04244	2.69755
NNE	0.02086	0.00545	0.00270	0.00180	0.00000	0.00000	0.03080	3.43182
NE	0.02381	0.01555	0.01650	0.00000	0.00000	0.00000	0.05586	4.54216
ENE	0.01013	0.01749	0.02481	0.00822	0.00093	0.00000	0.06158	7.18043
E	0.01986	0.01008	0.01569	0.00185	0.00000	0.00000	0.04748	5.02390
ESE	0.02111	0.01286	0.00461	0.00093	0.00000	0.00000	0.03950	3.73709
SE	0.01496	0.00736	0.00820	0.00000	0.00000	0.00000	0.03052	4.22401
SSE	0.02354	0.01280	0.01373	0.00365	0.00000	0.00090	0.05461	5.28546
S	0.02353	0.01931	0.02296	0.00365	0.00090	0.00000	0.07035	5.59192
SSW	0.02674	0.01385	0.01471	0.00458	0.00000	0.00000	0.05987	4.94611
SW	0.01869	0.01376	0.01201	0.00730	0.00090	0.00000	0.05266	5.97354
WSW	0.02800	0.02756	0.01743	0.00741	0.00000	0.00000	0.08040	5.32354
W	0.03276	0.03303	0.04314	0.05144	0.01182	0.00183	0.17401	8.89260
WNW	0.02208	0.01559	0.03205	0.02012	0.00643	0.00000	0.09627	8.07394
NW	0.01999	0.02018	0.02209	0.01185	0.00000	0.00000	0.07411	6.45783
NNW	0.01509	0.00817	0.00553	0.00090	0.00000	0.00000	0.02969	4.13108
Freq Ea WS Class	0.35176	0.24215	0.25884	0.12370	0.02097	0.00273	1.00015	6.07689

(Continued)

Table A-3
Seasonal/Annual Distribution of Wind Speed and Direction
At Lakehurst NAEC (1/76 to 12/77)
(Continued)

	Annual Wind Speed Class (knots)							Expected
	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	>21	Freq Ea Direction	Avg WS (knots)
N	0.01997	0.01074	0.00457	0.00000	0.00000	0.00000	0.03528	3.47222
NNE	0.00985	0.00570	0.00297	0.00137	0.00000	0.00000	0.01989	4.37481
NE	0.01143	0.00732	0.00800	0.00000	0.00000	0.00000	0.02675	4.55121
ENE	0.00830	0.01074	0.01508	0.00274	0.00046	0.00000	0.03732	6.43248
E	0.01198	0.01234	0.01508	0.00274	0.00000	0.00000	0.04214	5.81016
ESE	0.01307	0.01142	0.00617	0.00069	0.00000	0.00000	0.03135	4.41675
SE	0.01285	0.01119	0.00914	0.00137	0.00000	0.00000	0.03455	4.96122
SSE	0.02049	0.01281	0.01188	0.00366	0.00023	0.00046	0.04953	5.27973
S	0.02837	0.02400	0.02719	0.01142	0.00091	0.00023	0.09212	6.19963
SSW	0.01850	0.01531	0.01896	0.00685	0.00046	0.00000	0.06008	6.10311
SW	0.02321	0.01463	0.01782	0.00754	0.00091	0.00000	0.06411	5.90415
WSW	0.02231	0.02056	0.02215	0.01439	0.00160	0.00023	0.08124	6.83389
W	0.03547	0.03381	0.05048	0.05026	0.01599	0.00434	0.19035	9.17518
WNW	0.02259	0.01896	0.03061	0.02879	0.00617	0.00160	0.10872	8.61263
NW	0.01854	0.01965	0.02742	0.01805	0.00274	0.00046	0.08686	7.67701
NNW	0.01477	0.01006	0.01096	0.00366	0.00000	0.00023	0.03968	5.56968
Freq Ea WS Class	0.29170	0.23924	0.27848	0.15353	0.02947	0.00755	0.99997	6.82992

Source: Extracted from National Climatic Data Center data files.

Table A-4
Federal and State Ambient Air Quality Standards (AAQS)

Pollutant	Standard	Averaging Period	New Jersey (a)	National (b)
Sulfur Dioxide	Primary	12-month arith. mean	80 $\mu g/m^3$ (.03 ppm)	80 $\mu g/m^3$ (.03 ppm)
	Primary	24-hour average (c)	365 $\mu g/m^3$ (.14 ppm)	365 $\mu g/m^3$ (.14 ppm)
	Secondary	12-month arith. mean	60 $\mu g/m^3$ (.02 ppm)	---
	Secondary	24-hour average	260 $\mu g/m^3$ (.10 ppm)	---
	Secondary	3-hour average (c)	1,300 $\mu g/m^3$ (0.5 ppm)	1,300 $\mu g/m^3$ (0.5 ppm)
Total Suspended Particulates	Primary	12-month geom. mean	75 $\mu g/m^3$	---
	Primary	24-hour average	260 $\mu g/m^3$	---

a) New Jersey short-term standards are not to be exceeded more than once in any 12-month period.
b) National short-term standards are not to be exceeded more than once in a calendar year.
c) National standards are block averages rather than moving averages.
d) Intended as a guideline for achieving short-term standard.
e) National secondary standards for carbon monoxide have been dropped.
f) Maximum daily one-hour average over a three-year period. The expected number of days above the standard must be less than or equal to one.

(Continued)

Table A-4
Federal and State Ambient Air Quality Standards (AAQS)
(Continued)

Pollutant	Standard	Averaging Period	New Jersey (a)	National (b)
Total Suspended Particulates (Continued)	Secondary	12-month geom. mean (d)	60 $\mu g/m^3$	---
	Secondary	24-hour average	150 $\mu g/m^3$	---
Inhalable Particulates (PM_{10})	Primary and Secondary	Annual arith. mean	---	50 $\mu g/m^3$
	Primary and Secondary	24-hour average	---	150 $\mu g/m^3$
Carbon Monoxide	Primary and Secondary	8-hour average	10 mg/m^3 (9 ppm)	9 ppm (10 mg/m^3) (e)
	Primary and Secondary	1-hour average	40 mg/m^3 (35 ppm)	35 ppm (40 mg/m^3) (e)

a) New Jersey short-term standards are not to be exceeded more than once in any 12-month period.
b) National short-term standards are not to be exceeded more than once in a calendar year.
c) National standards are block averages rather than moving averages.
d) Intended as a guideline for achieving short-term standard.
e) National secondary standards for carbon monoxide have been dropped.
f) Maximum daily one-hour average over a three-year period. The expected number of days above the standard must be less than or equal to one.

Source: NJDEPE, 1989

(Continued)

Table A-4
Federal and State Ambient Air Quality Standards (AAQS)
(Continued)

Pollutant	Standard	Averaging Period	New Jersey (a)	National (b)
Ozone	Primary	Max. daily 1-hr. avg.	.12 ppm (235 $\mu g/m^3$)	.12 ppm (235 $\mu g/m^3$) (f)
	Secondary	1-hour average	.08 ppm (160 $\mu g/m^3$)	.12 ppm (235 $\mu g/m^3$) (f)
Nitrogen Dioxide	Primary and Secondary	12-month arith. mean	100 $\mu g/m^3$ (.05 ppm)	100 $\mu g/m^4$ (.05 ppm)
Lead	Primary and Secondary	3-month average	1.5 $\mu g/m^3$	---
	Primary and Secondary	Quarterly mean	---	1.5 $\mu g/m^3$

a) New Jersey short-term standards are not to be exceeded more than once in any 12-month period.
b) National short-term standards are not to be exceeded more than once in a calendar year.
c) National standards are block averages rather than moving averages.
d) Intended as a guideline for achieving short-term standard.
e) National secondary standards for carbon monoxide have been dropped.
f) Maximum daily one-hour average over a three-year period. The expected number of days above the standard must be less than or equal to one.

Source: NJDEPE, 1989.

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Appendix 3-4

Biology Methodology Development Report

May 1992

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1.0 INTRODUCTION

This document was prepared to support the analysis provided in the Environmental Impact Statement (EIS). The objective of this document is to supplement the EIS by providing the reader with information to augment and support the analysis provided in the EIS.

The objective of this document is to satisfy the Environmental Impact Analysis Process to addressing radioactive contamination at the BOMARC Missile Site. The scope of this report includes:

- a biological resource description
- data source identification
- a methodology for assessing current and future baseline conditions
- a methodology for assessing biological impacts
- impact criteria identification
- significance criteria identification.

2.0 BIOLOGICAL RESOURCE DESCRIPTION

Biological resources include the major components of the terrestrial and aquatic ecosystems potentially affected by the five alternatives considered for the BOMARC Missile Site. Conclusions stated concerning the status of biological resources were based on both site specific and regional (i.e., ecosystem level) information. The primary region of influence (ROI) of the BOMARC Missile Site is contained within an upland area of the Pinelands region (the New Jersey Pine Barrens). Because the daily ranges of many of the animals found in the primary ROI extend into local wetlands and due to other ecological relationships between uplands and lowlands, aquatic and terrestrial systems are treated together in the sections dealing with biological habitats. Major impacts resulting from physical disturbances may affect both the uplands area and lowlands area (the nearby wetlands) and these impacts can be best examined together in cause and effect relationships. Threatened and endangered species are treated separately because of legal requirements and the need for special consideration in the preservation of these species.

2.1 Biological Habitats

This discussion of biological habitats addresses all aspects (abiotic and biotic) of the general ecosystem within the ROI. Vegetation is described and treated as the foundation of the analysis in the habitat sections because of its role in primary production for the food chain. Wildlife species are treated as an integral component of the vegetative habitats present in the ROI. All components of terrestrial (upland), aquatic (lowland) or intergrade systems are treated at the ecosystem and population levels. Major emphasis is placed on biological habitats or species that represent especially important components of the ecosystem, are protected by law, or are highly regarded by natural resource management agencies. For example, some organisms, by virtue of their ecological niches (particularly burrowing and browsing mammals), may be greater or lesser impacted by the level of effectiveness inherent in any proposed remediation of the site. In discussion of these components, emphasis is also given to other species and biological communities that would be affected by the alternatives. For sampling and survey purposes, a

one-mile site grid (divided into 100-m^2 units) was developed for the site. The site grid is centered around Shelter 204 (the source of the contamination).

The individual vegetative habitats found within the one-square-mile grid which encompasses the site are described (Forman, 1985) as follows (see Figure 2-1):

- Oak-Pine Forest (OP) - This forest habitat type is the most prevalent at the site. Oak-Pine forest is usually dominated by black oak and pitch pine (*Quercus velutina* and *Pinus rigida*). The height of this type of forest habitat is approximately 40 feet. The total canopy cover is approximately 70 percent with about 60 percent of this cover contributed by oaks.

- White Cedar Swamp Forest (C) - This forest habitat type is located at the northwestern corner of the site grid surrounding an intermittent tributary of Jumping Brook. The eastern boundary of the wetland surrounding the Elisha Branch near the southeastern corner of the site grid also contains cedar swamp forest. Cedar Swamp Forests consist of high density stands of white cedars (*Chamae-cyparis thyoides*) with tall pitch pines randomly scattered throughout the canopy. Mature forest canopies are approximately 50 to 60 feet tall.

- Pitch Pine Lowland Forest (PPLL) - This forest habitat type is found along the Elisha Branch at the eastern side of the site grid and in the southwestern edge of the site grid. Pitch Pine Lowland Forests consist almost exclusively of pitch pine trees (90 percent or more) with red maple, blackgum and gray birch (*Acer rubrum, Nyssa Sylvatica* and *Betula populifolia*) composing a minor canopy component. This forest type has a relatively short canopy height (15 to 25 feet).

- Marsh - Marsh or Herbaceous Wetland habitat is located in the extreme southwestern portion of the site grid. Herbaceous wetland communities are generally devoid of forest habitat. Common vegetation cover of marsh habitat includes herbaceous emergent plants such as sedges, rushes, sphagnum mosses and chain ferns (*Carex* spp, *Juncus* spp, *Sphagnum* spp and *Woodwardia* 4 spp).

- Pine-Oak Forest (PO) - This forest habitat type is located in the western part of the site grid and to the northeast of the site grid. The Pine-Oak forest canopy consists primarily of pitch pine. Pitch pine makes up a minimum of 50 percent of the tree stems in this habitat type with various hardwood trees, particularly black oak, chestnut oak, scarlet oak and white oak (*Quercus velutina*, *Q. prinus*, *Q. Coccinea* and *Q. alba*) contributing less than 25 percent of the tree stems per unit area. In Pine-Oak forests, pitch pines average about 25 feet in height while blackjack oaks average about 20 feet in height.

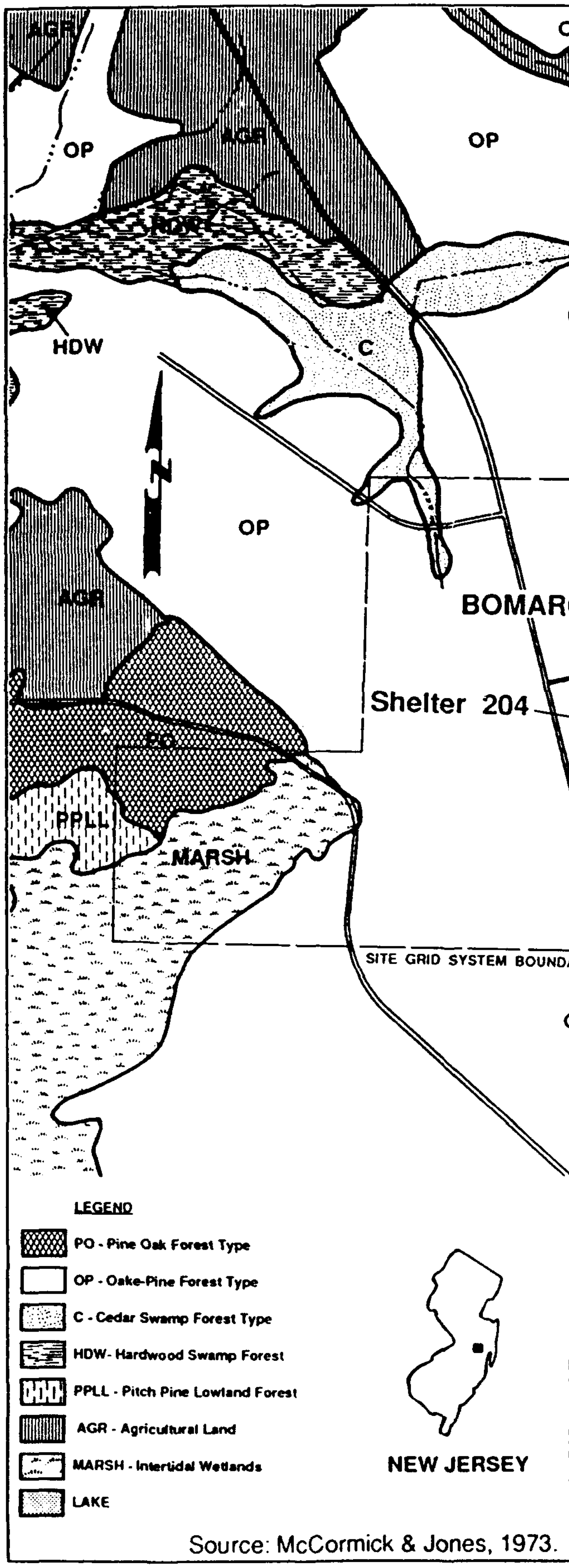

FIGURE 2-1

SITE HABITAT TYPE LOCATION MAP

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- Hardwood Swamp Forest (HDW) - Hardwood (Broadleaf) swamp forest habitat borders the cedar swamp habitat to the northwest of the grid area and also occurs to the northeast of the grid area. The trident red maple (*Acer rubrum*) is the principal species in this forest type. Blackgum and sweetbay (*Nyssa sylvatica* and *Magnolia virginiana*) are commonly associated with red maple in this forest type. Locally in some stands gray birch and sassafras (*Betula populifolia* and *Sassafras albidum*) are abundant. The canopy level of hardwood swamp forests are commonly 30 to 40 feet above the ground.

- Agricultural Land (AGR) - Agricultural land is located within a mile of the site grid toward the north and west of the site. In areas dominated by agriculture the natural vegetation has been displaced by cultigens maintained by agricultural practices.

Tables which contain lists of plant and animals species which may be found in the vicinity of the BOMARC Missile Site are provided as Annex A.

2.2 Threatened and Endangered Species

The threatened and endangered species section focuses on plant and animal species that are: (1) federally listed as threatened or endangered species; (2) are proposed for listing; and (3) are candidates for federal listing. Table 2-1 contains specific definitions of these terms. Table 2-2 lists rare, threatened, and endangered plant and animal species that have been recorded in the general vicinity of the BOMARC Missile Site. Table 2-3 provides the explanation of codes used in the preceding tables.

2.2.1 Federally Listed Species

The sources for the following information include the New Jersey Department of Environmental Protection and Energy (1987b, 1989b), Calazza and Fairbrothers (1980) and Correspondence from the U.S. Fish and Wildlife Service (January 28, 1992). Two state or federally listed threatened or endangered plant or wildlife species (Greene's rush and Sickle-leaved Golden Aster) were observed during the on-site biological reconnaissance. However, the threatened and endangered plants and wildlife listed below could potentially inhabit or utilize the habitat zones found within the BOMARC Missile Site ROI.

Federally Threatened Plant Species. The swamp-pink *(Helonias bullata)*, has been observed in the general vicinity of the BOMARC Missile Site and may potentially occur in the cedar swamp habitat zone. The knieskern's beaked-rush (*Rhynchospora knieskernii*) could potentially exist within the vicinity of the BOMARC Missile Site.

Federal Candidate Plant Species. The following are candidate species for the federal endangered and threatened plant species list and could potentially occur on the BOMARC Missile Site or its ROI:

Pine Barren reedgrass *(Calamovilfa brevipilis)*

Table 2-1
Federal Threatened and Endangered Species Categories

Category	Definition
Endangered	Taxa[1] threatened with extinction throughout all or a significant portion of their range.
Threatened	Taxa likely to become endangered in the foreseeable future.
Proposed Endangered	Taxa proposed to be formally listed as endangered.
Proposed Threatened	Taxa proposed to be formally listed as threatened.
Category 1[2]	Taxa for which the US Fish and Wildlife Service (USFWS) currently has on file substantial information on biological vulnerability and threat(s) to support the appropriateness of proposing to list them as endangered or threatened species. Presently, data are being gathered concerning precise boundaries for critical habitat designations. Development and publication of proposed rules on these taxa are anticipated, but because of the large number of such taxa, it could take several years before they are published. Also included in Category 1 are plant taxa whose status in the recent past is known, but may already have become extinct. These plants may retain a high priority for addition to the list subject to the confirmation of extant populations.
Category 2[2]	Taxa for which information now in possession of the USFWS indicates that proposing to list them as endangered or threatened species is possibly appropriate, but for which substantial data on biological vulnerability and threat(s) are not currently known or on file to support the immediate preparation of rules. Also included in Category 2 are plant taxa that are possibly extinct and taxonomical questionable taxa that are believed extinct in the wild, but are extant in cultivation. It is likely that some of these will not warrant listing, while others will be found to be in greater danger of extinction than some taxa in Category 1.
Category 3A	Taxa for which the USFWS has persuasive evidence of extinction. If rediscovered, however, such taxa might acquire high priority for listing. At this time, the best available information indicates that the taxa included in this subcategory, or the habitats from which they were known, are in fact extinct or destroyed, respectively.
Category 3B	Names that, on the basis of current taxonomic understanding, usually as represented in published revisions and monographs, do not represent taxa meeting the USFWS definition of "species." Such supposed taxa could be reevaluated in the future on the basis of subsequent research.
Category 3C	Taxa that have proven to be more abundant or widespread than was previously believed and/or those that are not subject to any identifiable threat. Should further research or changes in land use indicate significant decline in any of these taxa, they may be reevaluated for possible inclusion in Categories 1 or 2.

Notes:
[1]Taxon pl. Taxa = a taxonomic entity (species, sub-species, or variety) or a group of such entities.
[2]The taxa in Categories 1 and 2 are candidates for possible addition to the List of Endangered and Threatened Species. The USFWS encourages their consideration in environmental planning, such as in environmental impact analysis under the National Environmental Policy Act; however, none of the substantive or procedural provisions of the Endangered Species Act apply to a species that is designated as a candidate for listing.

Source: Federal Register, 1985.

Table 2-2
Rare, Threatened and Endangered Species in the BOMARC Missile Site Region

Scientific Name	Common Name	Federal Status	State Status	G-Rank	S-Rank	Date Observed	Identification
Ammodramus savannarum	Grasshopper sparrow		LT	G4	S3	1987-SUMMR	Y
Calamovilfa brevipilis	Pine Barren reedgrass	3C	LP	G3	S3	1985-08-29	Y
Carex barrattii	Barratt's sedge	3C	LP	G3	S3	1842-05-??	Y
Carex barrattii	Barratt's sedge	3C	LP	G3	S3	1985-05-14	Y
Carex barrattii	Barratt's sedge	3C	LP	G3	S3	1985-05-14	Y
Chrysopsis falcata	Sickled-leaved Chrysopsis				S3		
Clemmys insculpta	Wood turtle		LT	G5	S4	1987-SPRNG	Y
Clemmys muhlenbergii	Bog turtle	C2	LE	G4	S3	1987-SPRNG	Y
Crotalus horridus	Timber rattlesnake		LE	G5	S2	1931-07-18	Y
Crotalus horridus	Timber rattlesnake		LE	G5	S2	1932-07-??	Y
Enallagma recurvatum	Barrens bluet damselfly	3C		G3	S3	1987-05-25	Y
Enallagma recurvatum	Barrens bluet damselfly	3C		G3	S3	1987-05-25	Y
Enallagma recurvatum	Barrens bluet damselfly	3C		G3	S3	1987-06-06	Y
Enallagma recurvatum	Barrens bluet damselfly	3C		G3	S3	1987-06-06	Y
Helonias bullata	Swamp-pink	LT	LP	G2	S2	1942-01-25	Y
Helonias bullata	Swamp-pink	LT	LP	G2	S2	1956-05-06	Y
Helonias bullata	Swamp-pink	LT	LP	G2	S2	1908-04-30	Y
Hyla andersonii	Pine barrens treefrog		LE	G4	S4	1980-06-12	Y
Hyla andersonii	Pine barrens treefrog		LE	G4	S4	1975-06-19	Y
Hyla andersonii	Pine barrens treefrog		LE	G4	S4	1981-05-??	Y
Hyla andersonii	Pine barrens treefrog		LE	G4	S4	????-??-??	Y
Hyla andersonii	Pine barrens treefrog		LE	G4	S4	1983-05-19	Y
Juncus greenei	Greene's rush			G5	S2	1986-06-18	Y
Melanerpes erythrocephalus	Red-headed woodpecker		LT	G5	S3	1980-06-22	N
Melanerpes erythrocephalus	Red-headed woodpecker		LT	G5	S3	1981-06-16	Y
Pituophis melanoleucus	Pine snake		LT	G5	S3	1981-07-27	N
Pituophis melanoleucus	Pine snake		LT	G5	S3	1980-06-21	Y
Pituophis melanoleucus	Pine snake		LT	G5	S3	1987-08-29	Y
Pituophis melanoleucus	Pine snake	C2	LT	G5	S3	1982-06-09	Y
Scirpus longii	Long's bulrush		LP	G2	S2	1985-08-29	Y
Utricularia biflora	Two-flowered bladderwort			G5	S1	1975-06-25	

(Continued)

Table 2-2
Rare, Threatened and Endangered Species in the BOMARC Missile Site Region
(Continued)

Scientific Name	Common Name	Federal Status	State Status	G-Rank	S-Rank	Date Observed	Identification
Rhynchospora knieskernii	Kniesker's beaked-rush		T*				
Schwalbea americana	American chaffseed		PE*				
Eupatorium resinosum	Pine Barren's boneset		2*				
Narthecium americanum	Bog asphodel		1*				

Source: New Jersey Department of Environmental Protection and Energy, 1989b; *Correspondence from U.S. Fish and Wildlife Service, January 28, 1992.

Table 2-3
Explanation of Codes of Natural Heritage List

Federal Status Code

U.S. Fish and Wildlife Categories of Endangered and Threatened Plants and Animals

The following definitions are extracted from the September 27, 1985 U.S. Fish and Wildlife Service notice in the Federal Register:

LE--Taxa formally listed as endangered.

LT--Taxa formally listed as threatened.

PE--Taxa proposed to be formally listed as endangered.

PT--Taxa proposed to be formally listed as threatened.

S--Synonyms.

C1--Taxa for which the Service currently has on file substantial information on biological vulnerability and threat(s) to support the appropriateness of proposing to list them as endangered or threatened species.

C2--Taxa for which the Service is still seeking information on biological vulnerability and threat(s) to determine the appropriateness of listing them as endangered or threatened species, or taking them off the candidate list.

C3--Taxa that are no longer being considered for listing as threatened or endangered species. Such taxa are further coded to indicate three subcategories, depending on the reason(s) for removal from consideration.

State Status Codes

These refer to State listed nongame animals and Pinelands listed plants:

D	=	declining
EX	=	extirpated
I	=	introduced
IN	=	increasing
LE	=	state listed as endangered
LP	=	plants listed by the N.J. Pinelands Commission as threatened, endangered or rare
LT	=	state listed as threatened
P	=	peripheral
S	=	stable
SC	=	special concern
U	=	undetermined
U:SC	=	undetermined, of special concern
1	=	Taxa for which the Service currently has substantial information to support the appropriateness of proposing to list the species as threatened or endangered. Development and publication of proposed rules on these species is anticipated.
2	=	Taxa for which information now in possession of the Service indicates that proposing to list the species as threatened or endangered is possibly appropriate, but for which conclusive data are not available to support proposed rules at this time.
PE	=	Proposed Endangered species
T	=	Threatened species

Status for animals separated by a slash (/) indicate a duel status. First status refers to the state breeding population, and the second status refers to the migratory or winter population.

(Continued)

Table 2-3
Explanation of Codes of Natural Heritage List
(Continued)

State Element Ranks (S-Rank)

S1 = Critically imperiled in state because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres). Elements so ranked are often restricted to very specialized conditions or habitats and/or restricted to an extremely small geographical area of the state. Also included are elements which were formerly more abundant, but now through habitat destruction or some other critical factor of its biology have been demonstrably reduced in abundance. In essence, these are elements that even with intensive searching, sizable additional occurrences are unlikely to be discovered.

S2 = Imperiled in state because of rarity (6 to 20 occurrences). Historically many of these elements may have been more frequent but are now known from very few extant occurrences. Habitat destruction being the primary cause of their rarity. Diligent searching may yield additional occurrences.

S3 = Rare in state with 21 to 100 occurrences (plant species in this category have only 21 to 50 occurrences). Includes elements which are widely distributed in the state, with small populations/acreages or elements with restricted distribution, but locally abundant. Not yet imperiled instate, but may soon be if current trends continue. Searching often yields additional occurrences.

S4 = Apparently secure in state, with many occurrences.

Global Element Ranks (G-Rank, Nature Conservancy Rarity Ranking System)

G1 = Critically imperiled globally because of extreme rarity (five or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extinction.

G2 = Imperiled globally because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extinction throughout its range.

G3 = Either very rare and local throughout its range or found locally (even abundantly at some of its locations) in a restricted range (e.g., a single western state, a physiographic region in the East) or because of other factors making it vulnerable to extinction throughout its range; in terms of occurrences, in the range of 21 to 100.

G4 = Apparently secure globally, though it may be quite rare in parts of its range; especially at the periphery.

G5 = Demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.

Identification

This code refers to whether the identification of the species/community has been checked by a reliable individual and is indicative of significant habitat. Codes are as follows:

Y = Identification has been verified and is indicative of significant habitat.

BLANK = Identification has not been verified but there is no reason to believe it is not indicative of significant habitat.

? = Either it has not been determined if the record is indicative of significant habitat, or the identification of the species/community may be confusing or disputed.

Barratt's sedge *(Carex barrattii)*
Long's bulrush *(Scirpus longii)*
Pine Barren's boneset *(Eupatonum resinosum)*
Bog asphodel *(Narthecium americanium)*.

Federally Proposed Endangered Plant Species. The following species could potentially exist within the vicinity of the BOMARC Missile Site:

American chaffseed *(Schwalbea americana)*.

Federally Endangered Wildlife Species. The following species are known to occur in the Pinelands region of New Jersey.

Bald eagle *(Haliaeetus leucocephalus)*
Peregrine falcon *(Falco peregrinus)*.

Federal Candidate Wildlife Species. The following are candidate species for the federal endangered and threatened wildlife species list which potentially could inhabit the BOMARC Missile Site or its ROI:

Barren's blue damselfly *(Enallagma recurvatum)*
Bog turtle *(Clemmys muhlenbergii)*.

2.2.2 State Protected Species

New Jersey Threatened Plant Species. The following plant species are listed as threatened by the State of New Jersey and may occur on the BOMARC Missile Site or its ROI:

Stiff tick trefoil *(Desmodium strictum)*
Yellow-eyed grass *(Xyris flexuosa)*.

New Jersey Endangered Plant Species. The following plants are listed as endangered species by the State of New Jersey and may occur on the BOMARC Missile Site or its ROI:

Pine barrens gentian *(Gentiana autumnalis)*
Slender rattlesnake root *(Prenanthes autumnalis)*
Wand-like goldenrod *(Solidago stricta)*.

Other Sensitive Plant Species. The following plants are species of concern listed by the New Jersey Pinelands Commission (1980), which may occur on the BOMARC Missile Site or its ROI:

Pine barren reedgrass *(Calmovilfa brevipilis)*
Barratt's sedge *(Carex barrattii)*
Swamp-pink *(Helonias bullata)*
Long's bulrush *(Scirpus longii)*.

New Jersey Threatened Wildlife Species. The following list of animal species are those which are recorded by the NJDEPE (1989b) as being threatened in the state and could potentially inhabit the BOMARC Missile Site or its ROI:

American bittern *(Botaurus lentiginosus)*
Barred owl *(Strix varia)*
Grasshopper sparrow *(Ammodramus savannarum)*
Loggerhead shrike *(Lanius ladovicianus migrans)*
Merlin *(Falco columbarius)*
Mud salamander *(Pseudotriton montanus)*
Pine snake *(Pituophis melanoleucus)*
Red-headed woodpecker *(Melanerpes erythrocephalus)*
Red-shouldered hawk *(Buteo lineatus)*
Savannah sparrow *(Passerculus sandwichensis)*
Wood turtle *(Clemmys insculpta)*
Yellow-crowned night heron *(Nycticorax vgiolaceus)*.

The Barred Owl has been observed within one mile of the BOMARC Missile Site.

New Jersey Endangered Wildlife Species. The following list of animal species are those recorded by the NJDEPE (1989b) as being endangered in the state and potentially could inhabit the BOMARC Missile Site or its ROI:

Bog turtle *(Clemmys muhlenbergii)*
Cooper's hawk *(Accipiter cooperii)*
Corn snake *(Elaphe guttata)*
Loggerhead shrike *(Lanis ludovicianus migrans)*
Northern harrier *(Circus cyaneus)*
Peregrine falcon *(Falco peregrinus)*
Pie-billed grebe *(Podilymbus podiceps)*
Pine barrens treefrog *(Hyla andersonii)*
Piping plover *(Charadrius melodus)*
Sedge wren *(Cistothorous platensis)*
Short-eared owl *(Asio flammeus)*
Tiger salamander *(Ambystoma tigrinum)*
Timber rattlesnake *(Crotalus horridus)*.

2.2.3 BOMARC Missile Site Threatened Plant Species

Three populations (of 20 to 30 individuals each) of Greene's rush *(Juncus greenei)* were observed growing approximately 50 ft north of the north end of the electrical generator building on the BOMARC Missile Site. According to the Natural Heritage Program, Greene's rush is a rare and threatened plant and has the status of S-2 (imperiled) (Table 2-2 and Table 2-3 contain a complete explanation of codes of the Natural Heritage List).

A large population (several dozen individuals) of sickle-leaved golden aster *(Chrysopsis falcata)* was observed growing in the field on site just south of the southernmost row of missile shelters. According to the Natural Heritage Program, sickle-leaved golden aster is considered locally threatened or endangered in the New Jersey Pinelands and is given an S-3 status (rare).

2.3 Sensitive Habitats, Communities, and Populations

A cedar swamp forest habitat occurs approximately 0.20 miles east of the BOMARC Missile Site southeast boundary. This cedar swamp originates with the source of the Elisha Branch (located just south of the site) and follows a northwest direction for a distance of more than one mile.

A comprehensive field reconnaissance and systematic biological survey were not attempted for the cedar swamp habitat because of time and budgetary constraints. However, a limited field survey of the cedar swamp habitat was conducted on July 13, 1989.

The tree canopy consists of a mixture of white cedar *(Chamaecyparis thyoides)* and pitch pine *(Pinus rigida)*. Interspaced along the edges of the swamp zone were red maple *(Acer rubrum)* and white birch *(Betula populifolia)*. The shrub zone consisted of sweet pepperbrush *(Clethra alnifolia)* and blueberries (*Vaccinium* sp.). The dominant herbaceous plant species observed included bulrushes (*Scirpus* sp.), sundew (*Drosera* sp.), chainferns (*Woodwardia* sp.), and Sphagnum moss.

Sensitive plant and wildlife species potentially represented in the cedar swamp habitat include swamp-pink *(Helonias bullata*, formally listed as threatened on federal list); Greene's rush *(Juncus greenei)*; curley grass fern *(Schizaea pusilla*, rare but widely distributed in cedar swamp forests); the pine barrens treefrog *(Hyla andersonnii*, New Jersey Endangered Species); the barred owl *(Strix varia*, New Jersey threatened species), and the bog turtle *(Clemmys muhlenbergii*, candidate for the federal threatened and endangered wildlife species list).

The cedar swamp habitat area would meet the technical criteria for wetlands defined under Section 404 of the Clean Water Act of 1972. Therefore, prior to any site work which may impact this habitat (including fill and dredge activities) a permit would have to be issued through the U.S. Army Corps of Engineers.

2.4 Food Chains and Other Interspecies Relationships

Energy input (originating as sunlight) which flows through the pinelands ecosystem is initially captured and stored in green plants (producers). The energy stored in plants is then dispersed within the ecosystem through a series of feeding (trophic) levels. This pathway of energy transfers or series of trophic levels, representing energy flow through an ecosystem, is called the *food chain*. A typical food chain usually contains three to four (rarely more than five) levels. Herbivores (primary consumers) eat plants. Carnivores that eat herbivores are secondary consumers, and carnivores which eat secondary consumers are tertiary consumers. Consumers which feed on a variety of plants and animals are omnivorous. Carnivores which feed primarily on insects are insectivorous. Scavengers usually consume carrion. The Annex to Appendix 4,

Table A-17 summarizes trophic level information and diets of the mammals and common birds which inhabit or potentially inhabit the BOMARC Missile Site ROI.

Single entry food chains are usually oversimplifications since most consumers rely on a variety of food sources, often from more than one trophic level. Food webs consist of a number of interdependent food chains operating within a given ecosystem. The remainder of this section includes a discussion of fauna likely to occupy the tropic levels characteristic of the BOMARC Missile Site ROI. Sources of information used to characterize each trophic level include on-site observations, Penkala, *et al.*, (1980), Forman (1979), Palmer and Fowler (1975), McCormick (1970), and Palmer (1957).

2.4.1 <u>Herbivores</u>

Herbivores observed within the ROI include the eastern cottontail *(Sylvilagus floridanus)*, white-tailed deer *(Odocoileus virginianus)*, and the white-footed mouse *(Peromyscus leucopus)*. Other herbivores which may utilize ROI habitat include the woodchuck *(Marmota monax)*, the eastern chipmunk *(Tamias striatus)*, red-backed vole *(Pitymys pinetorum)*, song sparrows *(Melospiza melodia)*, ruffed grouse *(Bonasa umbellus)*, and the wild turkey *(Meleagris gallopavo)*. The eastern cottontail feeds on many of the herbs and grasses within the old field habitat on site. White-tailed deer are common forest edge browsers. Site ROI plants preferred by deer include sumac, cedar, pitch pine, oak, and wintergreen. The white-footed mouse feeds on the oak-pine forest habitat shrub zone berries (blueberries and huckleberries), as well as seeds and insects associated with the old field habitat.

2.4.2 <u>Carnivores</u>

Large carnivores including the black bear *(Ursus americanus)*, wolf *(Canis lupus)*, eastern coyote *(Canis latrans)*, and bobcat *(Lynx rufus)* have been eradicated from the pinelands region and are locally extinct. Other carnivores, such as the mink *(Mustela vison)* and long-tailed weasel *(Mustela frenata)*, are rare or poorly distributed in the vicinity of the BOMARC ROI. Carnivores likely to be found within the BOMARC ROI include the raccoon *(Procyon lotor)* and the gray fox *(Urocyon cinereoargenteus)*. The primary ROI food source for the gray fox would be the eastern cottontail. The raccoon's choice in ROI food resources would include the site's rodents and insects.

2.4.3 <u>Omnivorous</u>

Omnivorous consumers inhabiting or likely to inhabit the site ROI include the opossum *(Didelphis marsupialis)*, striped skunk *(Mephitis mephitis)*, red squirrel *(Tamiasciurus hudsonicus)*, flying squirrel *(Glaucomys volans)*, Norway rat *(Rattus norvegicus)*, house mouse *(Mus musculus)*, meadow jumping mouse *(Zapus hudsonius)*, common crow *(Corvus brachyrhynchos)*, catbird *(Dumetella carolinensis)*, robin *(Turdus migratorius)*, rufous-sided towhee *(Pipilo erythrophthalmus)*, chipping sparrows *(Spizella passerina)*, and the blue jay *(Perisoreus canadensis)*.

2.4.4 Insectivorous

Members of order Insectivora potentially inhabiting the BOMARC ROI are the masked shrew *(Sorex cinereus)*, short-tailed shrew *(Blarina brevicauda)*, least shrew *(Cryptotis parva)*, and eastern mole *(Scalopus aquaticus)*. Other potential ROI inhabitants which primarily consume insects include the bats and the indicated bird species.

2.4.5 Scavengers

The only scavenger which inhabits the BOMARC ROI is the turkey vulture *(Cathartes aura)*. Circling vultures were commonly sited during the EIS field work phase at the BOMARC Missile Site.

3.0 DATA SOURCE IDENTIFICATION

Biological analyses are dependent upon a detailed description of the existing biological resources. Detailed vegetation, habitat, and faunal inventories were required. In support of these surveys, data were collected from the existing technical literature, site-specific studies, and contacts with local officials.

3.1 Existing Technical Literature

Data sources employed in the vegetation/habitat mapping and survey included color aerial photographs, 1:58,000 color infrared aerial photographs, U.S. Geological Survey (USGS) topographic maps, USGS land use/land cover maps, New Jersey Department of Environmental Protection and Energy, Natural Heritage Program rare and exemplary natural community survey data, Pinelands Commission reports and other available maps and reports. Literature surveys and searches of computerized natural resources data bases (Natural Heritage Program data bases) were performed. These data sources were applied to the analysis of both biological habitats and threatened and endangered species.

3.2 Site Specific Studies

Field surveys (vegetative and habitat surveys) were conducted to verify the photointerpreted maps and to support impact analyses.

3.3 Discussions with Local Officials

Federal and state natural resources management agencies (e.g., the USFWS, the U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers [COE], and state fish and wildlife agencies), local experts, local university biology departments, and base environmental personnel were consulted to obtain current information on the status of the ecosystem in and around the site.

4.0 METHODS FOR ASSESSING EXISTING BASELINE CONDITIONS

A biological survey was conducted to assess the existing and future baseline conditions. Flora, fauna, and habitats were identified and described from field surveys and the existing literature. An attempt was made to trap mammals; one mouse was caught and analyzed for radioactive and radiogenic species to assess the degree of bioaccumulation.

4.1 Biological Habitats

Major vegetation and aquatic habitats within and near the site grid system were identified and mapped employing the above data sources and information collected from the on-site field surveys. Wildlife and plant species comprising each habitat type were identified for each habitat located within the site grid system.

Primary attention was given to those plant and animal species whose local populations might be reduced by program-related activities and regional communities that might be disturbed by program impacts. Unique habitats were identified through interviews with natural resource management agencies and informed local experts, university professors and through direct analysis of habitats in the potentially affected areas. These habitats' unique qualities, degree of legal protection (if any), and likelihood for improvement or degradation in the future (as a result of nonprogram-related activities) were analyzed. Projections of future conditions for biological resources in the ROI relies on both information acquired from direct analysis of the EIS survey data and information provided by natural resource management agencies and local planning groups.

4.2 Collection of Biological Data

Floral and faunal species inventories were compiled for each habitat type located within the site grid system. In addition, biological data were collected to define percent plant coverage and plant species density for each habitat type. The data categories and collection methodologies are summarized below:

- Plant Species Inventory - Stratified random sampling was accomplished within the site grid by reducing the grid divisions (to 10-m^2 units) within each habitat type, and randomly selecting sample units (10-m^2 units) for field collection and plant identification. Each sample unit selected for collection was chosen by employing a random number table. Sampling terminated when sample units yielded less than or equal to a 10 percent increase in total species identified (Phillips, 1959). For example, if 50 plant species had been identified for a habitat, and sample unit 8 contained 5 or fewer species not previously identified, then unit 8 was the final unit sampled.

- Percent Plant Cover - Percent foliar coverage is one common method used to quantify plant species dominance. For each sample unit a transect line was drawn and the length of transect intercepted by the canopy of a plant was recorded. The following equation was used to calculate percent foliar coverage (Westman, 1985):

$$\frac{\text{Sum of I}}{L} \times 100$$

where:

I = length of transect intercepted by the species of interest, and
L = total length of line transect observed.

- Plant Species Density - Plant species density measurements can be calculated from data generated for plants found within the sample units used in the plant species inventory.

  - Canopy Species Density: Canopy species are those plants which form the top most level of leaves and branches and include the tree form species found on-site. Canopy species density was calculated by dividing the total number of individuals of a species counted (using stems or trunks) by the total area sampled. (Phillips, 1959).

  - Ground Cover Species Density: Ground cover species are those plants which form the lower most level of leaves and branches and include the herbaceous plants (shrubs, ferns or wild flowers) found on-site. Ground cover species were represented by placing each ground cover species from the sample units into cover classes (modified from Phillips, 1959). The cover classes included the following: 1 - 5 percent, 5 - 25 percent, 25 - 50 percent, 50 - 75 percent, 75 - 95 percent, and 95 - 100 percent.

- Wildlife Species Inventory - An inventory of wildlife (including large animals [over 30 pounds], birds, small game [less than 30 pounds], reptiles and amphibians, and aquatic animals [fish, shellfish and waterfowl]) was compiled for the site. Where delineation was possible, wildlife species were tabulated by habitat type found on-site. Inclusion of wildlife species in this inventory was based on published surveys or inventory lists of wildlife whose ranges include the area occupied by the BOMARC Missile Site (wildlife potentially occurring at the site) and wildlife recorded during the on-site field survey. Field surveys were conducted by traversing the area contained in each habitat found within the site grid in 25-meter parallel transects until complete coverage of the habitat has been achieved. The wildlife species' presence were based on actual sighting or on the occurrence of positively identifiable signs (tracks, feathers, nests, eggs, scat, bones and other features).

4.3 Threatened and Endangered Species

Species evaluated included federally listed threatened and endangered species, proposed species, and federal candidate species. Species given special protection or status by state agencies were also considered. Occurrences of threatened and endangered species were compiled from data supplied by the USFWS, state agencies, computerized natural resources data bases, local experts, and base environmental personnel. Comprehensive tabulations of these species were compiled

for areas that could be affected by direct surface disturbance and potential indirect impacts near these areas.

Special attention was given to threatened and endangered species that are thought to occur within the direct disturbance area. Favorable habitats near known locations of sensitive species were inventoried to determine the presence of rare species. Permanent and important habitats used on a seasonal or transitory basis were also evaluated.

Information regarding regional and site-specific distributions, abundance, population status and prognosis, habitat requirements, recovery plans, and importance to national populations was reviewed for each threatened and endangered species that may be affected by the possible alternatives. This information, as well as assessments from natural resources managers, was used to assess future conditions for these species.

4.4 Organismic Contamination Analysis

In order to evaluate the site ecology as a potential contamination pathway, attempts were made to trap small mammals (white-footed mice, moles, voles or chipmunks) and analyze them for ^{241}Am and ^{239}Pu. After numerous attempts, one mouse was kill-trapped. After the mammal was trapped, it was preserved at 0°C and sent overnight to the contract lab for whole body analysis for plutonium and americium concentration.

5.0 METHODS FOR ASSESSING BIOLOGICAL RESOURCE IMPACTS

Site-level impacts were evaluated for all biological components (attributes) and an overall assessment was made for each attribute. The individual resource attributes evaluated in reference to level of impact include large animals (over 30 pounds), birds, small game (less than 30 pounds), reptiles and amphibians, aquatic animals (fish, shellfish, and waterfowl), field crops, endangered and threatened species, natural land vegetation and aquatic plants. Site-level impacts on biological resources were evaluated for areas that may be directly or indirectly disturbed. The emphasis was focused on placing site-level impacts in perspective with its relationship to the ecosystem level (Pine Barrens Region).

5.1 Biological Habitat

Impacts on existing biological habitats were assessed relative to the habitat changes expected to result. Overlay maps of zones of disturbance within the ROI were employed to determine and locate the habitats potentially affected. The locations and amounts of potential off-site disturbance were considered, including effects of erosion, siltation, dust, and excess water or water loss. As it relates to the ROI and adjacent areas, all possible impacts on local watersheds were considered for wetland or aquatic habitats (e.g., changes to water quality or other disturbances to aquatic wildlife). Behavioral disturbances of wildlife (e.g., displacement or disturbance to daily or seasonal mobility) were considered, in addition to the amount and type of wildlife habitat lost. Given the present population sizes of the wildlife species present (derived from published sources and the on-site survey), future habitat acreage (derived from the five alternatives) and present habitat acreage potential, post-impact wildlife population sizes can be estimated. These results aided in determining whether local populations of flora or fauna

would be diminished, or if any existing populations would have difficulty continuing their existence as a result of impacts. The extent of potential impacts was further described to the degree that local and regional biological communities would be disturbed, including consideration of recovery time. The ability of any assumed mitigations to reduce or eliminate impacts was also considered in evaluating the final impact. These assumed mitigations include general practices such as soil stabilization and revegetation.

5.2 Threatened and Endangered Species

Specific actions and alternatives program-related activities were analyzed to determine impacts on threatened and endangered species, and whether the species affected are federally listed, proposed, candidates, or state recognized (see Table 2-1 for specific definitions). The types of impacts to be evaluated include direct mortality, displacement, loss of habitat or a habitat component, noise pollution, disturbance of daily/seasonal movements or activities, and stress.

6.0 LEVELS OF IMPACT CRITERIA

The level of impact (LOI) represents the biological magnitude of the expected disturbances (i.e., the effect on the condition of populations, habitats, and ecological systems). The expected overall impacts on biological resources are categorized as negligible, low, moderate, or high. The same LOIs and criteria for defining them were employed in describing short- and long-duration impacts. The criteria used for defining the LOIs are as follows:

- Negligible Impact -- No disruption to sensitive or critical habitats is expected. No disruption to populations of desirable species would be expected. The potential for bioassimilation of radionuclides is reduced.

- Low Impact -- Potential disruption to sensitive or critical habitats is expected. Potential disruption to populations of desirable species would be expected. The potential for bioassimilation of radionuclides would be potentially increased.

- Moderate Impact -- Actual disruption to sensitive or critical habitats is expected. Actual disruption to populations of desirable species would be expected with negative ramifications on ecosystems expected. The potential for bioassimilation of radionuclides would be actually increased.

- High Impact -- Severe disruption to sensitive or critical habitats is expected. Severe disruption to populations of desirable species would be expected. The potential for bioassimilation of radionuclides would be severely increased.

7.0 SIGNIFICANCE CRITERIA

The significance of impacts on biological resources were evaluated in accordance with the context and intensity criteria provided in the Council on Environmental Quality (CEQ) regulations (40 CFR 1508.27). Ten items are outlined in the CEQ regulations which were considered in evaluating the significance of an impact:

- Beneficial as well as adverse impacts
- Effects on public health and safety
- Unique (e.g., historic, scenic, etc.) features of the area
- Effects on the environment which are likely to be controversial
- Effects on the environment which are uncertain or unknown
- Actions establishing a precedent with significant effects
- Actions contributing to significant cumulative impact
- Adverse effects on scientific, cultural or historic places
- Adverse effects on a threatened or endangered species
- Actions threatening a violation of Federal, state or local laws.

An important criteria for evaluating the significance of ecological impacts at the BOMARC Missile Site was the plutonium and americium concentrations derived from chemical analyses of organisms collected within the ROI. These analyses are necessary to adequately assess the potential impact of bioassimilation of the site's contaminants. Any analytical results indicating organismic ^{239}Pu or ^{241}Am concentrations above normal background levels or above instrument detection levels was considered a level of concern. The severity of impact would be proportional to the level of contaminant concentration.

In addition to the CEQ criteria for biological resources impacts, the concepts of intensity and context include the potential of an impact to affect a wider array of ecologically related biological resources than the directly affected resource, and the potential to affect the scientific, recreational, economic, or aesthetic value of the resource. These criteria are not necessarily dependent on the duration of an impact. Therefore, the same criteria apply to short- and long-duration impacts.

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Annex A

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Table A-1
Vascular Plants Identified: Oak Pine Vegetative Zone

Scientific Name	Common Name
Pinus rigida	Pitch Pine
Quercus prinus	Chestnut oak
Quercus marilandica	Blackjack oak
Quercus velutina	Black oak
Quercus stellata	Post oak
Quercus ilicifolia	Scrub or Bear Oak
*Sassafras albidum**	Sassafras
Gaylussacia frondosa	Dangleberry
Gaylussacia baccata	Black huckleberry
Vaccinium vacillans	Lowbush blueberry
Vaccinium corymbosum	Highbush blueberry
Smilax glauca	Glaucous-leaved greenbarrier
Gautheria procumbens	Wintergreen
*Gramineae or Poaceae***	Grass family species
Pteridium aquilnium	Bracken fern
Tephrosia virginiana	Goat's rue
Hypericum gentianoides	Pineweed, Orange grass

* Identified in the Oak-Pine Vegetative Zone but not located within one of the sample units.
** Absence of inflorescence prevented identification to species level.

Table A-2
Trees Per Acre: Oak-Pine Vegetative Zone (Totals)

Species	Total Number of Trees	Total Area (Acres)	Trees per Acre
Pinus rigida	40	0.15	267
Quercus prinus	20	0.15	133
Quercus ilicifolia	6	0.15	40
Quercus velutina	5	0.15	33
Quercus marilandica	3	0.15	20
Quercus stellata	2	0.15	13
Total *Quercus* species	36	0.75	239
TOTALS (*Quercus and Pinus*)	76	0.95	506

Table A-3
Canopy Cover: Oak-Pine Vegetative Zone,
(Totals for six 10 m^2 units)

Species	Length of Total Transect Lines (feet)	Total Length of 6 Transect Lines (feet)	Total Percent Coverage	Percent of Total Coverage
Pinus rigida	*100*	*300*	*33%*	*49%*
Quercus prinus	*50*	*300*	*17%*	*25%*
Quercus velutina	*28*	*300*	*9%*	*13%*
Quercus marilandica	*15*	*300*	*5%*	*7%*
Quercus stellata	*13*	*300*	*4%*	*6%*
Quercus ilicifolia	*0*	*300*	*0%*	*0%*
Total (Quercus species)	*106*	*300*	*35%*	*51*
TOTAL (Quercus and Pinus)	*206*	*300*	*68%*	*100%*

Table A-4
Vegetative Cover Classes*:
Oak-Pine Vegetative Zone
(Totals from 30 1-m^2 quadrants)

	Cover Class					
	1.5%	5.25%	25-50%	50-75%	75-95%	95-100%
Species (Common Name)	Lowbush** Blueberry (6)	Scrub oak (11)	Dangleberry (5)	Black Huckleberry (6)	Black Huckleberry (2)	
	Glaucous-leaved Greenbrier (4)	Lowbush Blueberry (11)	Black Huckleberry (3)	Dangleberry (2)		
	Scrub Oak (3)	Dangleberry (8)	Lowbush Blueberry (2)	Scrub Oak (2)		
	Wintergreen (1)	Black Huckleberry (9)	Scrub Oak (2)	Lowbush Blueberry (1)		
	Bracken Fern (1)					
	Pitch Pine (1)					

* Includes both herbaceous plants and shrubs (10ft or less).
** Numbers in parentheses represent the number of quadrants in which the species occurred within each cover class category.

Table A-5
Vascular Plants Identified:
Old Field Vegetative Zone

Scientific Name	Common Name
Erigeron annuus	Daisy Fleabane
*Taraxacum sp.**	Dandelion
Plantago lanceolata	Buckhorn Plantain
Oxalis stricta	Upright Yellow Wood Sorrel
Potentilla recta	Upright Cinquefoil
Parthenocissus quinquefolia	Virginia Creeper
Convolvulus sepium	Hedge Bindweed
Ambrosia artemisiifolia	Common Ragweed
Achillea millefolium	Yarrow
Trifolium agrarium	Yellow Hop Clover
Arenaria serpyllifolia	Thymeleaf Sandwort
Trifolium arvense	Rabbitfoot Clover
Asclepias tuberosa	Butterfly Weed
Aster dumosus	Bushy Aster
Dianthus armeria	Deptford Pink
Baptisia tinctoria	Wild Indigo
*Eupatorium sp.**	Joe-Pie-Weed genus
Ranunculus acris	Meadow Buttercup
Allium sativum	..d Garlic
Tragopogon major	Yellow Goat's Beard
Prunus virginiana	Choke Cherry
Elymus virginicus	Virginia Wild Rye
*Lolium sp.**	Rye Grass
Phalaris arundinacea	Reed Canary Grass
Bromus japonicus	Japanese Bromegrass
Bromus secalinus	Chess Grass
Comptonia peregrina	Sweet Fern
Rubus hispidus	Swamp Dewberry
Smilax glauca	Glancous-Leaved Greenbrier
Hypochoeris radicata	Cats-Ear
Krigia virginica	Dwarf Dandelion
Lespedeza virginica	Virginia Bushclover
Opuntia humifusa	Prickley-Pear Cactus
Pyxidanthera barbulata	Pyxie Moss
Panicum polyanthes	Many Flowered Panic Grass
Sassafras albidum	Sassafras
Juniperus virginiana	Red Cedar
Pinus rigida	Pitch Pine
Quercus ilicifolia	Scrub Oak
Chrysanthemum leucanthemum	Ox-Eye Daisy
*Bromus sp.**	Broom Grass
Trioda flava	Purple-Top Grass
Allium canadense	Meadow Garlic
*Solanum sp.**	Nightshade
Hypericum gentianoides	Pineweed
Rudbeckia hirta	Black-Eyed Susan

(Continued)

Table A-5
Vascular Plants Identified:
Old Field Vegetative Zone
(Continued)

Scientific Name	Common Name
Xyris flexuosa	Yellow-Eyed Grass
*Digitaria sp.**	Crab Grass
Cyperus filiculmis	Sedge
Quercus marilandica	Blackjack Oak
Eupatorium hyssopifolium	Hyssop-Leaved Thoroughwort
*Asclepias sp.**	Milkweed
*Solidago sp.**	Golden Rod
*Aster sp.**	Aster
Panicum implicatum	Tangled Panic Grass
*Gramineae or Poaceae**	Grass Family Member
Rhus copallina	Shining Sumac
Phytolacca americana	Pokeweed
Plantago virginica	Dwarf Plantain
Rhus radicans	Poison Oak
Asclepias syriaca	Common Milkweed
Vitis aestivalis	Summer Grape
Festuca rubra	Red Fescue
Cirsium vulgare	Common Thistle
Cassia fasciculata	Partridge Pea
Liquidambar styraciflua	Sweetgum
Cinna arundinacea	Wood Reedgrass
Juncus greenei	Greene's Rush
Erigeron canadensis	Horseweed
Solidago puberula	Downy Goldenrod
Verbascum blattaria	Moth Mullein
Lespedeza capitata	Bushclover
Cornus florida	Flowering Dogwood
Smilax rotundifolia	Common Greenbrier
Cyperus ferax	Sedge
Cenchrus tribuloides	Sandbur
Oenothera laciniata	Cut-Leaved Evening Primrose
Trifolium pratense	Red Clover
Vitis rupestris	Sand Grape
Asclepias purpurascens	Purple Milkweed
Viburnum recognitum	Smooth Arrowroot
Lespedexa cuneata	Sericea
Rhexia virginica	Meadow Beauty
Chrysopsis falcata	Sickle-leaved Chrysopsis

*Absence of Flower parts or other diagnostic features prevented species level identification.

Table A-6
Vegetative Cover Classes*: Old Field Vegetative Zone (Totals from 20 1-m^2 quadrants)

	Cover Class					
	1-5%	5-25%	25-50%	50-75%	75-95%	95-100%
Species (Common Name)	Rabbitfoot Clover (4)**	Chess Grass (3)	Chess Grass (2)	Rye Grass Sp. (1)***	Chess Grass (3)	
	Red Fescue (3)	Red Fescue (3)	Crab-grass (2)***	Meadow Buttercup (1)	Virginia Wild Rye (1)	
	Hyssop-Leaved Boneset (3)	Many Flowered Panic Grass (2)	Japanese Brome-grass (1)	Virginia Wild Rye (1)	Crab-grass Sp. (1)***	
	Aster Sp (3)***	Sweet Fern (2)	Purple-top Grass (1)	Crabgrass Sp. (1)***		
	Yellow Hop Clover (1)	Purpletop Grass (2)		Tangled Panic Grass (1)		
	Meadow Buttercup (1)	Virginia Wild Rye (1)				
	Rye Grass Sp. (1)***	Virginia Bushclover (1)				
	Wild Garlic (1)	Yarrow (1)				
	Sweet Fern (1)	Crabgrass Sp. (1)***				
	Scrub Oak (1)	Tangled Panic Grass (1)				
	Goldenrod Sp. (1)***	Bushy Aster (1)				
	Broom Grass Sp. (1)***					

* Includes both herbaceous plants and shrubs (10ft or less).
** Numbers in parentheses represent the number of quadrants the species occurred within each cover class category.
*** Absence of flower parts or other diagnostic features prevented species level identification.

Table A-7
Game and Furbearing Mammals of Ocean County

Opossum
Raccoon
Longtail weasel
Mink
River otter
Stripped skunk
Red fox
Grey fox
Black bear*
Bob cat*
Eastern coyote*
Grey Squirrel
Red squirrel
Woodchuck
Beaver
Muskrat
Eastern cottontail
Whitetail deer

*Potential Habitat

Source: Penkala, Hahn and Sweger, 1980.

Table A-8
Small Mammals of Ocean County

Masked shrew
Short-tailed shrew
Least shrew
Eastern mole
Little brown bat
Eastern pipistrel
Big brown bat
E. chipmunk
Flying squirrel
Rice rat
White-footed mouse
Red backed vole
Meadow vole
Pine vole
Southern bog lemming
Norway rat
House mouse
Meadow jumping mouse

Source: Penkala, Hahn and Sweger, 1980.

Table A-9
Pinelands Mammals

ORDER MARSUPIALIA - Pouched Mammals

Opossum (*Didelphis marsupialis*)	Occasional throughout the Pine Region.

ORDER INSECTIVORA - Insect Eaters

Masked Shrew (*Sorex cinereus*)	Common in open lowland sites.
Short-tailed Shrew (*Blarina brevicauda*)	Occasional throughout the Pine Region.
Least Shrew (*Cryptotis parva*)	This species is occasional or rare in the Pine Region, but common in brackish meadows along the Wading River.
Eastern Mole (*Scalopus aquaticus*)	Common throughout the Pine Region.
Star-nosed Mole (*Condylura cristata*)	Rare to occasional in lowland areas. Specimen found dead on snow in Lebanon State Forest.

ORDER CHIROPTERA - Bats

Little Brown Myotis (*Myotis lucifugus*)	Stable Population
Eastern Pipistrelle (*Pipistrellus subflavus*)	Undetermined Population
Big Brown Bat (*Eptesicus fucus*)	Specimen from Toms River.

ORDER LAGOMORPHA - Hares and Rabbits

Eastern Cottontail (*Sylvilagus floridanus*)	Common throughout the Pine Barrens.

ORDER RODENTIA - Rodents

Eastern Chipmunk (*Tamias striatus*)	Rare to occasional throughout the Pine Region.
Woodchuck (*Marmota monax*)	Rare in most of the Pine Region, but occasional in cultivated areas near towns.
Gray Squirrel (*Sciurus carolinensis*)	Occasional throughout the Pine Region, particularly in oak forests and around towns.
Red Squirrel (*Tamiasciurus hudsonicus*)	Common throughout the Pine Region. Locally known as "Chickaree."
Southern Flying Squirrel (*Glaucomys volans*)	Not often seen, but probably common throughout the Pine Region. Several individuals seen in Lebanon State Forest.
Beaver (*Castor canadensis*)	Apparently all native beaver became extinct in the Pine Barrens about 1820. Introduced beavers are reported to be thriving at several places in the region.
Rice Rat (*Oryzomys palustris*)	This species may occur in marshes along the Mullica River.
White-footed Mouse (*Peromyscus leucopus*)	Common throughout the Pine Region.

(Continued)

Table A-9
Pinelands Mammals
(Continued)

ORDER RODENTIA - Rodents (Continued)	
Red-backed Mouse (*Clethrionomys gapperi*)	Common in lowland sites, particularly in cedar swamps. The dark race of this species (C.g. rhoadsi) is endemic to the New Jersey Pine Barrens.
Meadow Vole (*Microtus pennsylvanicus*)	Occasional to common in lowland areas, particularly in marshes along the Mullica and Wading Rivers. In some years, these voles are pests in cranberry bogs.
Pine Vole (*Pitymys pinetorum*)	Common throughout the Pine Region. Tunnels of this vole are conspicuous in upland sites.
Muskrat (*Ondatra zibethica*)	Rare in the central Pine Region, but occasional to frequent near Atlantic Coast and along the Mullica and Wading Rivers.
Southern Bog Lemming (*Synaptomys cooperi*)	An occasional small mammal in lowland sites with shrub or sedge vegetation.
Norway Rat (*Rattus norvegicus*)	Common around settlements.
House Mouse (*Mus Musculus*)	Common around settlements.
Meadow Jumping Mouse (*Zapus hudsonius*)	This species is widely distributed in the Pine Region and to be most numerous in open bogs and near streams.
ORDER CARNIVORA - Flesh Eaters	
Red Fox (*Vulpes fulva*)	It may occur in some tidal river meadows, but none have been recorded.
Gray Fox (*Urocyon cinereoargenteus*)	Common throughout the Pine Region.
Raccoon (*Procyon lotor*)	Frequent throughout the Pine Region.
Long-tailed Weasel (*Mustela frenata*)	Frequent along streams.
Mink (*Mustela vison*)	Occasional along streams.
Striped Skunk (*Mephitis mephitis*)	Rare, except along margins of the Pine Region.
River Otter (*Lutra canadensis*)	Occasional along streams.
ORDER ARTIODACTYLA - Even-toed Hoofed Mammals	
White-tailed Deer (*Odocoileus virginianus*)	Common throughout the Pine Region. Nearly extinct by 1904 owing to hunting and trapping. Restocked in 1904 with imported animals.

Source: McCormick, 1970, and Status of Indigenous Nongame Wildlife Species of New Jersey, 1987.

Table A-10
Preferred Habitats of Common Pineland Breeding Birds

Common Name	Scientific Name	Preferred Habitat
Screech Owl	Otus asio	Oak and Pine Forest
Downy Woodpecker	Dendrocopos pubescens	Oak and Pine Forest
Blue Jay	Cyanocitta cristata	Oak and Pine Forest
Carolina Chickadee	Parus carolinensis	Oak and Pine Forest
Tufted Titmouse	Parus bicolor	Oak and Pine Forest
Red-eyed Vireo	Vireo olivaceus	Oak and Pine Forest
Ovenbird	Seiurus aurocapillus	Oak and Pine Forest
Black-and-White Warbler	Mniotilta varia	Oak and Pine Forest
Whip-poor-will	Caprimulgus vociferus	Pine Forest with Shrubs
Rufous-sided Towhee	Pipilo erythrophthalmus	Pine Forest with Shrubs
Pine Warbler	Dendroica pinus	Pine Forest with Shrubs
Prairie Warbler	Dendroica discolor	Pine Forest with Shrubs
Brown Thrasher	Toxostoma rufum	Pine Forest with Shrubs
Eastern Wood Pewee	Contopus virens	Cedar Swamps Forest with Shrubs
Catbird	Dumetella carolinensis	Cedar Swamps Forest with Shrubs
Yellow-throated Vireo	Vireo flavifrons	Cedar Swamps Forest with Shrubs
Yellowthrout	Geothlypis trichas	Cedar Swamps Forest with Shrubs
Redstart	Setophaga ruticilla	Cedar Swamps Forest with Shrubs
Song Sparrow	Melospiza melodia	Cedar Swamps Forest with Shrubs

Source: Forman (Ed), 1979.

Table A-11
Game Birds of Ocean County

Mute swan	Common eider
Whistling swan	King eider
Canada goose	White-winged scoter
Atlantic brant	Surf scoter
Snow goose	Common scoter
Mallard	Ruddy duck
Gadwall	Hooded merganser
Black duck	Am merganser
Pintail	Red breasted merganser
Green-wing teal	Ruffed grouse
Blue-wing teal	Bob white
Am. widgeon	Turkey*
Shoveller	Clapper rail
Wood duck	Virginia rail
Redhead	Sora rail
Ring necked duck	Common gallinule
Canvasback	American coot
Greater scaup	American woodcock
Lesser scaup	Common snipe
Am. goldeneye	Common crow
Buffelhead	Fish crow
Old squaw	

*Potential habitat

Source: Penkala, Hahn and Sweger, 1980.

Table A-12
Pinelands Birds

Pied-billed Grebe (*Podilymbus podiceps*): Transient, but may winter where there is open water.

Great Blue Heron (*Ardea herodias*): Occasional along larger streams; permanent resident.

Green Heron (*Butorides virescens*): Common summer resident.

Common Egret (*Casmerodius albus*): Frequent summer visitor to ponds and open streams.

Black-crowned Night Heron (*Nycticorax nycticorax*): Frequent summer resident.

Mallard (*Anas platyrhynchos*): Transient, but may winter where there is open water.

Black Duck (*Anas rubripes*): Occasional on cranberry reservoirs and other ponds; permanent resident.

Wood Duck (*Aix sponsa*): Frequent along larger streams; nests in tree holes; summer resident.

Hooded Merganser (*Lophodytes cucullatus*): Occasional transient, but may winter where there is open water.

*Turkey Vulture (*Cathartes aura*): Common permanent resident.

Red-tailed Hawk (*Buteo jamaicensis*): Uncommon permanent resident; noted as breeding at Lakehurst.

Red-shouldered Hawk (*Buteo lineatus*): Uncommon permanent resident.

Broad-winged Hawk (*Buteo platypterus*): Common summer resident.

Golden Eagle (*Aquila chrysaetos*): Rare, observed at Quaker Bridge in 1950.

Bald Eagle (*Haliaeetus leucocephalus*): Rare along coast; may have formerly nested in cedar swamps.

Marsh Hawk (*Circus cyaneus*): Occasional visitor from coast.

Osprey (*Pandion haliaetus*): Formerly common near coast, but numbers recently have declined; summer resident.

Pigeon Hawk (*Falco columbarius*): Transient, but regularly observed in autumn over the Plains.

Sparrow Hawk (*Falco sparverius*): Common permanent resident.

Ruffed Grouse (*Bonasa umbellus*): Common in upland areas, especially where scrub oak forms extensive cover; permanent resident.

Heath Hen (*Tympanuchus cupido*): Once abundant in the Plains areas, it became extinct in the region about 1870. The Heath Hen was an eastern subspecies of the Greater Prairie Chicken.

Bobwhite (*Colinus virginianus*): Occasional to frequent in upland forests and clearings; form introduced stock.

Ring-necked Pheasant (*Phasianus colchicus*): Rare to occasional; introduced as a game bird.

(Continued)

Table A-12
Pinelands Birds
(Continued)

Turkey (*Melegris gallopavo*): Believed once to have been common throughout the state. In recent years, several attempts have been made to reintroduce the Turkey in the Pine Barrens. In the spring of 1958 or 1959, 20 pen-raised birds from Pennsylvania were released on the Wharton Tract near Quaker Bridge. Twenty more birds were freed during the following year at Atsion. For several years after these releases, birds and their signs were noted by a number of observers, but no poults were seen. No evidence of the birds has been found since about 1964.

King Rail (*Rallus elegans*): Said to nest in cedar swamps.

Killdear (*Charadrius vociferus*): Occasional in disturbed areas, as around newly constructed ponds; summer or permanent resident.

American Woodcock (*Philohela minor*): Occasional permanent resident.

Spotted Sandpiper (*Actitis macularia*): Occasional around cleared areas; summer resident.

Solitary Sandpiper (*Tringa solitaria*): In open, sandy areas among cedar swamps; transient.

*Mourning Dove (*Zenaidura macroura*): Common. Permanent resident.

Yellow-billed Cuckoo (*Coccyzus americanus*): Occasional near streams; summer resident.

Black-billed Cuckoo (*Coccyzus erythropthalmus*): Occasional, less common than the Yellow-billed Cuckoo; summer resident.

Barn Owl (*Tyto alba*): Rare, a specimen (NJSM 141) secured on 27 August 1968 at Williamstown, Gloucester County, by W. Maley.

Screech Owl (*Otus asio*): Common, nests in tree holes; permanent resident.

Great Horned Owl (*Bubo virginianus*): Occasional, but generally distributed; permanent resident.

Short-eared Owl (*Asio flammeus*): Rare, near coast; permanent resident.

Saw-whet Owl (*Aegolius acadicus*): Irregular winter resident.

Chuck-will's widow (*Caprimulgus carolinensis*): Rare, but apparently extending distribution northward from Cape May.

Whip-poor-will (*Caprimulgus vociferus*): Common summer resident.

Common Nighthawk (*Chordeiles minor*): Locally common in recently burned areas; summer resident.

Chimney Swift (*Chatera pelagica*): Common near houses and occasional nesting in hollow trees; summer resident.

Ruby-throated Hummingbird (*Archilochus colubris*): Locally common on lowland shrubs; summer resident.

Belted Kingfisher (*Megaceryle alcyon*): Occasional along larger streams and ponds; summer resident.

Yellow-shafted Flicker (*Colaptes auratus*): Common throughout the year.

Red-bellied Woodpecker (*Centurs carolinus*): Rare summer visitant.

Yellow-bellied Sapsucker (*Sphyrapicus varius*): Occasional around orchards; transient.

(Continued)

Table A-12
Pinelands Birds
(Continued)

Hairy Woodpecker (*Dendrocopos villosus*): Common permanent resident.

Downy Woodpecker (*Dendrocopos pubescens*): Common permanent resident.

Eastern Kingbird (*Tyrannus tyrannus*): Common summer resident.

Great Crested Fly catcher (*Myia. .us crinitus*): Common summer resident.

Eastern Phoebe (*Sayornis phoebe*): Common summer resident.

Acadian Flycatcher (*Empidonax virescens*): Rare summer resident.

Trail's Flycatcher (*Empidonax traillii*): Rare, usually near ponds; summer resident.

Least Flycatcher (*Empidonax minimus*): Rare nested at Batsto and Pleasant Mills, but at few points in unsettled areas; summer resident.

Eastern Wood Pewee (*Contopus virens*): Common in cedar swamps; summer resident.

Tree Swallow (*Iridoprocne bicolor*): Common; especially along larger streams; summer resident.

Rough-winged Swallow (*Stelgidopteryx ruficollis serripennis*): Locally common; transient.

*Barn Swallow (*Hirundo rustica erythrogaster*): Common summer resident.

Cliff Swallow (*Petrochelidon pyrrhonota*): A rare transient, said to have formerly bred commonly in the Pine Barrens.

Purple Martin (*Progne subis*): Common along larger streams; nests in buildings, boxes and rarely in tree holes; summer resident.

Blue Jay (*Cyanocitta cristata*): Common in upland forests; permanent resident.

*Common Crow (*Corvus brachyrhynchos*): Common permanent resident.

Fish Crow (*Corvus ossifragus*): Frequent near coast; nests in pines.

Black-capped Chickadee (*Parus atricapillus*): Infrequent during summer, but more common in winter.

Carolina Chickadee (*Parus carolinensis*): Nests in hollow trees; very common permanent resident.

Tufted Titmouse (*Parus bicolor*): Occasional; nests in tree holes; permanent.

White-breasted Nuthatch (*Sitta carolinensis*): Occasional to common; nests in tree holes; permanent resident.

Red-breasted Nuthatch (*Sitta canadensis*): Erratic autumn and spring migrant, observed at Lakehurst and Medford Lakes.

Brown Creeper (*Certhia familiaris*): An unusual northern species reported near Browns Mills in 1950 and Quaker Bridge in 1958 and 1959.

House Wren (*Troglodytes aedon*): Occasional near dwellings, but also found to nest in tree holes near streams; summer resident.

(Continued)

Table A-12
Pinelands Birds
(Continued)

Carolina Wren (*Thryothorus ludovicianus*): Frequent permanent resident.

Long-billed Marsh Wren (*Telatodytes palustris*): Along streams near coast; summer resident.

Mockingbird (*Mimus polyglottos*): Occasional to common near roadsides and houses; summer or permanent resident.

*Catbird (*Dumetella carolinensis*): Common near streams; summer resident.

Brown Thrasher (*Toxostoma rufum*): Common in upland forests and in the Plains summer resident.

*Robin (*Turdus migratorius*): Common summer or permanent resident.

Wood Thrust (*Hylocichla mustelina*): Occasional in dense cedar swamps; summer resident.

Hermit Thrush (*Hylocichla guttala*): Common spring and autumn migrant.

Swainson's Thrush (*Hylocichla ustulata*): Occasional to common migrant.

Gray-cheeked Thrush (*Hyl[illegible] minima*): Occasional to common migrant.

Veery (*Hylocihla fuscesc[illegible]s*): Frequent autumn migrant.

*Eastern Bluebird (*Sialia sialis*): Occasional near settlements; nests in boxes and occasionally in tree holes; permanent or summer resident.

Blue-gray Gnatcatcher (*Polioptila caerulea*): Rare, near coast; summer resident.

Golden-crowned Kinglet (*Regulus satrapa*): Winter visitant.

Ruby-crowned Kinglet (*Regulus calendula*): Transient occasionally wintering in cedar swamps.

Cedar Waxwing (*Bombycilla cedrorum*): Occasional permanent resident.

Loggerhead Shrike (*Lanius ludovicianus*): Occasional in Cape May County; migrant.

Starling (*Sturnus vulgaris*): Common permanent resident in open areas.

White-eyed Vireo (*Vireo griseus*): Common in swamp forests; summer resident.

Yellow-throated Vireo (*Vireo flavifrons*): Transient.

Red-eyed Vireo (*Vireo olivaceus*): Common in uplands, especially among young oaks; summer resident.

Black-and-white Warbler (*Mniotilta varia*): Common throughout Pine Region; summer resident.

Prothonotay Warbler (*Portonotaria citrea*): Local in mixed cedar maple-gum swamp forests; summer resident.

Golden-winged Warbler (*Vermivora chrysoptera*): Scarce transient.

Blue-winged Warbler (*Vermivora pinus*): Occasional in tall pine forests with scrub oak undergrowth; summer resident.

(Continued)

Table A-12
Pinelands Birds
(Continued)

Tennessee Warbler (*Vermivora peregrina*): Occasional autumn transient.

Parula Warbler (*Parula americana*): Common in cedar swamps with old-man's beard lichen (Usnea) on trees; summer resident.

Yellow Warbler (*Dendroica petechia*): Common along larger streams; summer resident.

Magnolia Warbler (*Dendroica magnolia*): Transient.

Cape May Warbler (*Dendroica tigrina*): Rare transient.

Black-throated Blue Warbler (*Dendroica caerulescens*): Transient.

Myrtle Warbler (*Dendroica coronata*): Transient, but may winter near coast.

Black-throated Green Warbler (*Dendroica virens*): Rare summer resident.

Blackpoll Warbler (*Dendrocia striata*): Common transient.

Pine Warbler (*Dendrocia pinus*): Common in forests with taller pines; summer resident.

Prairie Warbler (*Dendroica discolor*): Common in upland areas with dense shrub cover, including the Plains; summer resident.

Palm Warbler (*Dendroica palmarum*): Transient.

Ovenbird (*Seirus aurocapillus*): Common in upland forests; summer resident.

Northern Waterthrush (*Seirus noveboracensis*): Occasional to common migrant.

Yellowthroat (*Geothlypis trichas*): Very common in lowland forest, frequent in upland areas, and reported from the Plains summer resident.

Yellow-breasted Chat (*Icteria virens*): Occasional along streams; summer resident.

Hooded Warbler (*Wilsonia citrina*): Common in cedar swamp forest; summer resident.

Wilson's Warbler (*Wilsonia pusilla*): Frequent transient.

American Redstart (*Setophaga ruticilla*): Locally abundant in swamp forests; summer resident.

House Sparrow (*Passer domesticus*): Frequent around dwellings; permanent resident.

Eastern Meadowlark (*Strunella magna*): Occasional in cultivated areas and along coastal marshes; summer resident.

Red-winged Blackbird (*Agelaius phoeniceus*): Common along larger streams and on edges of coastal marshes; summer or permanent resident.

Orchard Oriole (*Icterus spurius*): Occasional near west end of Pine Region; summer resident.

Baltimore Oriole (*Icterus galbula*): Rare, nested in red maples at Pine Lake Park, Ocean County, in 1938 and 1952; summer resident and migrant visitor.

(Continued)

Table A-12
Pinelands Birds
(Continued)

Common Grackle (*Quiscalus quiscula*): Rare, except near settlements; summer or permanent resident.

Brown-headed Cowbird (*Molothrus ater*): Occasional to common summer resident.

Scarlet Tanager (*Piranga olivacea*): Occasional, usually in sprout oak forests; summer resident.

Cardinal (*Richmondena cardinalis*): Occasional in uplands and swamp forest edges; permanent resident.

Rose-breasted Grosbeak (*Pheucticus ludovicianus*): Occasional transient.

Indigo Bunting (*Passerina cyanea*): Occasional to rare in sprout oak forests; summer resident.

Evening Grosbeak (*Hesperiphona vespertina*): Regular winter visitor.

Purple Finch (*Carpodacus purpureus*): Occasional to common winter visitor.

Common Redpoll (*Acanthis flammea*): Occasional to common winter visitor.

Pine Siskin (*Spinus pinus*): Regular winter visitant.

American Goldfinch (*Spinus tristis*): Frequent permanent resident.

Red Crossbill (*Loxia curvirostra*): Sporadic winter visitor.

*Rufous-sided Towhee (*Pipilo erythrophthalmus*): The most common nesting species in upland forests of the Pine Barrens, especially in those with dense undergrowth, including the Plains summer or permanent resident.

Henslow's Sparrow (*Passerherbulus henslowii*): Rare, usually in grassy marshes and cranberry bogs; summer resident.

Sharp-tailed Sparrow (*Ammospiza caudacuta*): Stream edges near coast; transient or summer resident.

Seaside Sparrow (*Ammospiza maritima*): Stream edges near coast; summer resident.

Vesper Sparrow (*Pooecetes gramineus*): Rare, except in cultivated areas; summer resident.

Slate-colored Junco (*Junco hyemalis*): Regular winter visitant.

*Chipping Sparrow (*Spizella passerina*): Common around dwellings; summer resident.

Field Sparrow (*Spizella pusilla*): Common along water courses, but also reported from the Plains; summer or permanent resident.

White-throated Sparrow (*Zonotrichia albicollis*): Frequent transient; winter resident at feeding stations.

Fox Sparrow (*Passerella iliaca*): Rare migrant; rare winter visitor.
Swamp Sparrow (*Melospiza georgiana*): Nests in sedge savannas; summer resident or transient.

Song Sparrow (*Melospiza melodia*): Common permanent resident.

* Observed at BOMARC Missile Site

Source: McCormick, 1970.

Table A-13
Pinelands Reptiles

Turtles

Common Snapping Turtle (*Chelydra s. serpentina*)
Eastern Painted Turtle (*Chrysemsys p. picta*)
Spotted Turtle (*Clemmys guttata*)
Wood Turtle (*Clemmys insculpta*)
Bog Turtle (*Clemmys muhlenbergii*)
Mud trutle (*Kinosternon s. subrubrum*)
Red-bellied Turtle (*Pseudemys rubriventris*)
Stinkpot (*Sternotherus odoratus*)
Eastern Box Turtle (*Terrapene c. carolina*)

Lizards

Five-lined Skink (*Eumeces fasciatus*)
+*Ground Skink (*Lygosoma laterale*)
Northern Fence Lizard (*Sceloporous undulatus hyacinthus*). Locally known as pine tree lizard.

Snakes

Eastern Worm Snake (*Carphophis a. amoenus*)
+*Scarlet Snake (*Cemophora coccinea*)
Northern Black Racer (*Coluber c. constrictor*)
Timber Rattlesnake (*Crotalus h. horridus*). The only venomous snake in the Pine Barrens.
Ringneck Snake (*Diadophis p. punctatus x edwardsi*). Intergrading population.
+*Corn Snake (*Elaphe g. guttata*)
Black Rat Snake (*Elaphe o. obsoleta*)
Eastern Earth Snake (*Virginia v. valeriae*). A very scarce snake in New Jersey. Recorded from 2 localities on the edge of the Pine Barrens, but not within the region.
Eastern Hognose Snake (*Heterodon platyrhinos*)
+Coastal Plain Milk Snake (*Lampropeltis doliata trangulum x temporalis*). Intergrading population.
+Eastern Kingsnake (*Lampropeltis g. getulus*)
Northern Water Snake (*Natrix s. sipedon*)
+Rough Green Snake (*Opheodrys aestivus*)
+*Northern Pine Snake (*Pituophis m. melanoleucus*)
Northern Brown Snake (*Storeria d. dekayi*)
Northern Red-Bellied Snake (*Storeria o. occipitomaculata*)
Eastern Ribbon Snake (*Thamnophis s. sauritus*)
Eastern Garter Snake (*Thamnophis s. sirtalis*)

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*New Jersey distribution limited, or nearly so, to the Pine Barrens.
+Reaches northern limit of distribution in New Jersey Pine Barrens.

Source: McCormick, 1970.

Table A-14
Pinelands Amphibians

Salamanders

Marbled Salamander (*Ambystoma opacum*)
Spotted Salamander (*Ambystoma maculatum*). There is only one record for this species in the Pine Barrens.
Eastern Tiger Salamander (*Ambystoma t. tigrinum*)
Four-toed Salamander (*Hemidactylium scutatum*)
Red-backed Salamander (*Plethodon c. cinereus*)
Northern Two-lined Salamander (*Eurycea b. bislineata*)
Northern Dusky Salamander (*Desmognathus. f. fuscus*). Rare; there are only two records from the Pine Barrens.
Red-spotted Newt (*Notophthalmus v. viridescens*)
Northern Red Salamander (*Pseudotriton r. ruber*)
+*Eastern Mud Salamander (*Pseudotriton m. montanus*). Rare; known only since 1953 from one locality on the west edge of the region.

Frogs and Toads

Northern Cricket Frog (*Acris c. crepitans*)
Fowler's Toad (*Bufo woodhousei fowleri*)
+*Pine Barrens Treefrog (*Hyla andersoni*). Outside the New Jersey Pine Barrens, this colorful treefrog is known only from two small areas in the south. It was first discovered near Jackson Camden County and was believed to be rare until the early 1900's. Now it is known to be abundant throughout the Pine Barrens and to occur in the Spotswood outlier just south of New Brunswick.
Northern Spring Peeper (*Hyla c. crucifer*)
Eastern Gray Treefrog (*Hyla v. versicolor*)
New Jersey Chorus Frog (*Pseudacris triseriata kalmi*)
Bullfrog (*Rana catesbeiana melanota*)
Green Frog (*Rana clamitans*)
Pickerel Frog (*Rana palustris*)
+Southern Leopard Frog (*Rana pipiens sphenocephala*). Probably the most abundant frog in the Pine Barrens.
Wood Frog (*Rana sylvatica*)
+*Carpenter Frog (*Rana virgatipes*). This species is rare outside New Jersey Pine Barrens. Its common name refers to the hammer-like sound of this frog's mating call. The carpenter frog is well distributed in the Pine Barrens and locally is abundant.
Spadefoot Toad (*Scaphiopus holbrooki*)

*New Jersey distribution limited, or nearly so, to the Pine Barrens.
+Reaches northern limit of distribution in New Jersey Pine Barrens.

Source: McCormick, 1970.

Table A-15
Pinelands Fishes

ORDER SALMONIFORMES - Salmon and Herring-like Fish

Family Esocidae

Redfin Pickerel (*Esox americanus*)
Chain Pickerel (*Esox niger*)
Northern Pike (*Esox lucius*). Introduced in Union Lake, Millville.

Family Unbridae

Eastern Mudminnow (*Umbra pygmaea*)

ORDER CYPRINIFORMS - Carp

Family Cyprinidae

Goldern Shiner (*Notemigonus crysoleucas*)
Ironcolor Shiner (*Notropis chalybaeus*)

Family Castostomidae

White Sucker (*Catostomus commersoni*)
Creek Chubsucker (*Erimyzon oblongus*)

ORDER SILURIFORMES - Catfish

Family Ictaluridae

Yellow Bullhead (*Ictalus natalis*)
Brown Bullhead (*Ictalus nebulosus*)
Tadpole Madtom (*Noturus gyrinus*)

ORDER ANGULLIFORMES - Eels

Family Anguillidae

American Eel (*Anguilla rostrata*)

ORDER ATHERINIFORMES - Topminnows and Killfish

Family Cyprinodontidae

Banded Killfish (*Fundulus diaphanus*)

Table A-15
Pinelands Fishes
(Continued)

ORDER PERCOPSIFORMES - Pirate Perch

Family Aphredoderidae

Pirate Perch (*Aphredoderus sayanus)*

ORDER PERCIFIORMES - Perch-like Fish

Family Centrarchidae

Mud Sunfish (Acantharchus pomotis)
Blackbanded Sunfish (*Enneacanthus chaetodon*)
Banded Sunfish (*Enneacanthus obesus*)
Bluespotted Sunfish (*Enneacanthus gloriosus*)
Redbreast Sunfish (*Lepomis auritus*)
Pumpkinseed (*Lepomis gibbosus*)

Family Percidae

Yellow Perch (*Perca flavescens*)
Johnny Darter (*Etheostoma olmstedi*)
Swamp Darter (*Etheostoma fusiforme*)

Family Centrachidae

Smallmouth Bass (*Micropterus dolomieui*)

Source: McCormick, 1970.

Table A-16
Pineland Invertebrates
Insects of Dry Woods*

Order	Common Name(s)**	Family	Common Name(s)**	Total Number of Species
Isoptera	Termites	Termitidae	Soldierless, Dessert and Nasutiform Termites	1
Corrodentia (Psocoptera) Neuroptera	Booklice, Barklice Fishflies, Snakeflies, Lacewings and Antlions	Psocidae	Barklice	2
Odonata	Dragonflies and Damselflies	Chrysopidae	Green Lacewings	1
		Mantispidae	Mantid Flies	2
		Myrmeleonidae	Antlions	1
		Libellulidae	Skimmer	3
Thysanoptera Homoptera	Thrips Cicada, Hoppers, Whiteflies, Aphids and Scale Insects	Thripidae	Common Thrip	2
		Cicadidae	Cicadas	3
		Membracidae	Treehoppers	6
		Fulgoridae	Fulgorid	3
		Cerropidae	Planthoppers and Sprittlebugs	1
		Cicadellidae	Leafhoppers	16
		Aphididae	Aphids	1
		Coccidae	Wax and Tortoise Scales	1

(Continued)

Table A-16
Pineland Invertebrates
Insects of Dry Woods*
(Continued)

Order	Common Name(s)**	Family	Common Name(s)**	Total Number of Species
Hemiptera	Bugs	Aradidae	Flat or Fungus Bugs	1
		Miridae	Leaf or Plant Bugs	13
		Pentatomidae	Stink Bugs	5
		Tingididae	Lace Bugs	1
		Reduviidae	Assassin Bugs	4
Orthoptera	Grasshoppers, Katydids, Crickets, Mantids, Walking Sticks, Cockroaches	Blattidae	Cockroaches	1
		Acridiidae	Short-Horned Grasshoppers	18
		Gryllidae	Crickets	3
Coleptera	Beetles	Staphylinidae	Rove Beetles	5
		Erotylidae	Pleasing Fungus Beetles	1
			Sap Beetles	
		Nitidulidae	Minute Tree-fungus Beetles	1
		Cisidae	Darkling Beetles	1

(Continued)

Table A-16
Pineland Invertebrates
Insects of Dry Woods*
(Continued)

Order	Common Name(s)**	Family	Common Name(s)**	Total Number of Species
Coleptera (Continued)	Beatles	Tenebrionidae	Ground Beetles	6
		Carabidae	Ladybird Beetles	4
		Coccinellidae	Click Beetles	13
		Elateridae	Long-Horned Beetles	8
		Cerambycidae	Flat Bark Beetles	4
		Cucujidae	Snout Beetles	1
		Curculionidae	Metallic Wood-Boring	11
			Beetles	8
		Buprestidae	Scarab Beetles	
		Scarabaeidae	Blister Beetles	1
		Meloidae	Shining Flower Beetles	1
		Phalacridae	Dermestid Beetles	1
		Dermestidae	Fireflies	7
		Lampyridae	Soft-winged Flower Beetles	1
		Malachidae		
		Cleridae	Checkered Beetles	15
		Chrysomelidae	Leaf Beetles	1
		Bruchidae	Seed Beetles	4
		Cisterlidae	Comb-Clawed Beetles	
		(Alleculidae)		3
		Melandryidae	False Darkling Beetles	1
		Oedermeridae	False Blister Beetles	2
		Mordellidae	Tumbling Flower Beetles	4

(Continued)

Table A-16
Pineland Invertebrates
Insects of Dry Woods*
(Continued)

Order	Common Name(s)**	Family	Common Name(s)**	Total Number of Species
Coleoptera (Continued)	Beetles	Rhynchitidae	Rhynchitids	4
		Otiorhynchidae	Otiorhynchids	2
		Attelabidae	Attelabids	2
Lepidoptera	Butterflies and Moths	Lycaenidae	Gossamer-Winged Butterflies	1
			Common Skippers	
		Hesperidae	Sphinz or Hawk Moths	1
		Sphingidae	Giant Silkworm Moths	1
		Saturniidae	Tiger Moths	1
		Arctiidae and (Lithosiidae)	Hemileucids	1
		Hemileucidae	Noctuid Moths	7
		Noctuidae	Hypenids	2
		Hypenidae	Geometer Moths	3
		Geometridae	Window-Winged Moths	1
		Thyridae	Pyralid Moths	5
		Pyralidae	Tortricid Moths	6
		Tortricidae	Ermine Moths	1
		Yponomeutidae	Gelechiid Moths	1
		Gelechiidae	Clothes Moths	1
		Tineidae		1

(Continued)

Table A-16
Pineland Invertebrates
Insects of Dry Woods*
(Continued)

Order	Common Name(s)**	Family	Common Name(s)**	Total Number of Species
Hymenoptera	Ichneumons, Chalcids, Ants,	Formicidae	Ants	17
	Wasps, and Bees	Scoliidae	Scoliid Wasps	2
		Colletidae	Yellow-Faced and Plasterer Bees	2
		Megalchilidae	Leafcutting Bees	2
		Cynipidae	Cynipids	15
		Tenthredinidae	Sawflies	5
		Braconidae	Braconids	6
		Ichneumonidae	Ichneumons	12
		Perilampidae	Perilampids	3
		Eurytomidae	Eurytomids or seed Chalcids)	1
			Chalcidids	
		Chalcididae	Velvet Ants	5
		Mutillidae	Tiphiid Wasps	1
		Tiphiidae	Potter Wasps	4
		Eumenidae	Vespid Wasps	3
		Vespidae	Spider Wasps	2
		Pompilidae	Sphecid Wasps	4
		Sphecidae	Bembecids	2
		Bembecidae	Nitelids	1
		Nitelidae	Halictid Bees	1
		Halictidae	Panurgids	2
		Panurgidae		1

(Continued)

Table A-16
Pineland Invertebrates
Insects of Dry Woods*
(Continued)

Order	Common Name(s)**	Family	Common Name(s)**	Total Number of Species
Diptera	Flies	Bombyliidae	Bee Flies	5
		Asilidae	Robber Flies	5
		Sarcophagidae	Flesh Flies	2
		Culicidae	Mosquitoes	1
		Mycetophilidae	Fungus Gnats	1
		Bibionidae	March Flies	1
		Stratiomyidae	Soldier Flies	1
		Tabanidae	Horse and Deer Flies	4
		Therevidae	Stiletto Flies	2
		Dolichopodidae	Long-Legged Flies	3
		Empidae (Empididae)	Dance Flies	1
		Syrphidae	Syrphid Flies	1
		Tachinidae	Tachinid Flies	4
		Dexidae	Dexid Flies	1
		Muscidae	Muscid Flies	3
		Sapromyzidae (Lauxaniidae)	Lauxaniid Flies	2
		Trypetidae (Tephritidae)	Fruit Flies	1
		Dscinidae (Chloropidae)	Fruit Flies	1

* Based on data from H. Weiss and E. West, 1924 whose survey location was approximately 7 miles east of the BOMARC Missile Site.
** D.J. Borro and R. E. White, 1970 (Source for common names).

Table A-17
Trophic Level Data of Mammals and Birds
Potentially Inhabiting the BOMARC Missile Site ROI

Common Name	Scientific Name	Feeding Strategy**	Food Source
Mammals			
Opossum	*Didelphis marsupialis*	O	Eggs, Carrion, Insects, Fruit, Grain
Raccoon	*Procyon lotor*	C	Insects, Aquatic Animals, Domestic Crops, Fruit
Long-tailed Weasel	*Mustela frenata*	C	Small Mammals, Aquatic Animals, Birds, Insects
Mink	*Mustela vison*	C	Rodents, Fish, Amphibians
Striped Skunk*	*Mephitis mephitis*	O	Insects, Fruit, Rodents, Grain
Red Fox	*Vulpes fulva*	C	Rabbits, Rodents, Small Animals, Grain
Grey Fox	*Urocyon cinereoargenteus*	C	Rabbits, Rodents, Small Animals, Vegetable Matter
Red Squirrel	*Tamiasciurus hudsonicus*	O	Seeds, Birds, Eggs, Fruit
Woodchuck	*Marmota monax*	H	Pasture and Grain Crops
Eastern Cottontail*	*Sylvilagus floridanus*	H	Herbs, Bark, Vegetables

(Continued)

Table A-17
Trophic Level Data of Mammals and Birds
Potentially Inhabiting the BOMARC Missile Site ROI
(Continued)

Common Name	Scientific Name	Feeding Strategy**	Food Source
Mammals (Continued)			
White Tail Deer*	*Odocoileus virginianus*	H	Twigs and Leaves of Trees
Masked Shrew	*Sorex cinereus*	I	Insects and Small Animals
Short-tailed Shrew	*Blarina brevicauda*	I	Insects and Small Animals
Least Shrew	*Cryptotis parva*	I	Insects and Small Animals
Eastern Mole	*Scalopus aquaticus*	I	Invertebrates
Little Brown Bat	*Myotis lucifugus*	I	Insects
Eastern Pipistrel	*Pipistrellus subflavus*	I	Insects
Big Brown Bat	*Eptesicus fuscus*	I	Insects
Eastern Chipmunk	*Tamias striatus*	H	Nuts, Fruit, Seeds, Some Small Animals
Flying Squirrel	*Glaucomys volans*	O	Seeds, Nuts, Eggs, Insects, Some Animal Matter
White-Footed Mouse*	*Peromyscus leucopus*	H	Blueberries, Huckleberries, Seeds, Arthropods

(Continued)

Table A-17
Trophic Level Data of Mammals and Birds
Potentially Inhabiting the BOMARC Missile Site ROI
(Continued)

Common Name	Scientific Name	Feeding Strategy**	Food Source
Mammals (Continued)			
Redbacked Vole	*Clethrionomy gapperi*	H	Green Veg., Seeds, Insects
Pine Vole	*Pitymys pinetorum*	H	Seeds, Bulbs, Tubers
Norway Rat	*Rattus norvegicus*	H	Almost Any Organic Matter
House Mouse	*Mus musculus*	O	Variety of Plant and Animal Matter
Meadow Jumping Mouse	*Zapus hudsonius*	O	Seeds, Insects, Fruit
Birds			
Turkey Vulture*	*Cathartes aura*	S	Carrion
Barn Swallow*	*Hirundo rustica erythrogaster*	I	Insects
Common Crow*	*Corvus brach-yrhynchos*	O	Insects, Carrion, Seeds, Eggs
Catbird*	*Dumetella carolinensis*	O	Insects, Fruit, Vegetable Matter
Robin*	*Turdus migratorius*	O	Mostly Insects, Earthworms, Vegetable Matter
Eastern Bluebird*	*Sialia sialis*	I	Mostly Insects, Fruit

(Continued)

Table A-17
Trophic Level Data of Mammals and Birds
Potentially Inhabiting the BOMARC Missile Site ROI
(Continued)

Common Name	Scientific Name	Feeding Strategy**	Food Source
Birds (Continued)			
Rufuous-sided Towhee*	*Pipilo erythrophthalmus*	O	Mostly Insects, Fruit
Chipping Sparrows*	*Spizella p. passerina*	O	Seeds, Fruits, Insects
Screech owl	*Otus asio*	I	Insects and Seeds
Downy woodpecker	*Dendrocopos pubescens*	O	Mostly Insects, Some Mice, Small Animals
Blue Jay	*Perisoreus canadensis*	I	Mostly Insects, Bark, Sap, Seeds
Carolina chickadee	*Parus carolinensis*	I	Insects, Vegetable Matter
Tufted titmouse	*Parus bicolor*	I	Nuts, Acorns, Insects
Red-eyed vireo	*Vireo olivaceus*	I	Insects
Ovenbird	*Seiurus aurocapillus*	I	Insects
Black-and-white warbler	*Mniotilta varia*	I	Insects
Whip-poor-will	*Caprimulgus vociferus*	I	Insects
Pine warbler	*Dendroica pinus*	I	Insects
Brown thrasher	*Toxostoma r. rufum*	I	Insects, Spiders, Worms

(Continued)

Table A-17
Trophic Level Data of Mammals and Birds
Potentially Inhabiting the BOMARC Missile Site ROI
(Continued)

Common Name	Scientific Name	Feeding Strategy**	Food Source
Birds (Continued)			
Eastern Wood Pewee	*Contopus virens*	I	Insects
Yellow-throated Vireo	*Vireo flavifrons*	I	Insects
Yellowthroat	*Geothlypis trichas*	I	Insect
Redstart	*Setophaga ruticilla*	I	Insects
Song Sparrow	*Melospiza melodia*	H	Vegetable Matter (Mostly Seeds), Insects
Ruffed Grouse	*Bonasa umbellus*	H	Acorns, Nuts, Buds, Fruit
Bob White	*Colinus virginianus*	I	Insects
Turkey	*Meleagris galloparo*	H	Seeds, Nuts, Grain, Insects

*Observed within BOMARC Missile Site ROI 6/6 - 9/89

**I Insectivorous
H Herbivorous
O Omnivorous
C Carnivorous
S Scavenger

Sources: Penkala, Hahn and Sweger, 1980; Forman (Ed.), 1979; Palmer and Folwer, 1975.

Appendix 3-5

Land Use Methodology Development Report

May 1992

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TABLE OF CONTENTS

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1.0 INTRODUCTION

This document was prepared to support the analysis provided in the Environmental Impact Statement (EIS). The objective of this document is to supplement the EIS by providing the reader with information to augment and support the analysis provided in the EIS.

This Methodology Development Report (MDR) includes discussions of methods used to provide:

- A description of existing and future land uses, including a discussion of local and regional development issues and a description of current land-use activities
- An outline of the methods for assessing the baseline condition (existing land uses)
- A methodology for assessing the impacts on land use.

2.0 LAND USE DESCRIPTION

The BOMARC Missile Site is located in a rural portion of Ocean County, New Jersey. The entire site is fenced; a second fence encloses the area around Shed 204, where the fire occurred. Access to the site is through an access road that enters Route 539 at the midpoint between Route 527 and State Route 70. A detailed description of land use near the BOMARC Missile Site is provided in Section 3.6 of the EIS.

2.1 Existing Land Uses

The land uses immediately surrounding the site include three Federal military installations: Fort Dix, McGuire AFB, and Lakehurst Naval Air and Engineering Center. Aside from these Government facilities, the State of New Jersey owns the National Guard Facility to the northwest of the site and the Colliers Mills Wildlife Management Area. Current activities, proximity of employment centers, and base housing are described.

2.2 Local Land Uses (Development Within a Five-Mile Radius of the Site)

There is one community, New Egypt, partially located within a five-mile radius of the site. This area has not experienced as much pressure for development as other communities in the region.

2.3 Future Land Uses

There are four factors influencing the future development in the area. These include (1) implementation of the Pinelands Comprehensive Management Plan, (2) continued operation of existing Federal installations, (3) proposed developments currently under consideration by local planning officials, and (4) farmland preservation programs.

2.4 Land Use Restrictions

There are a number of land use plans that were reviewed. These include (1) the New Jersey Pinelands Comprehensive Management Plan, (2) the Ocean County Comprehensive Master Plan, and (3) other local plans/programs.

3.0 DATA SOURCE IDENTIFICATION

Land-use analysis is dependent upon local comprehensive plans, maps, and aerial photographs. Because the BOMARC Missile Site is located in the Pinelands National Preserve, adjacent to three major Federal installations, and a State park, a number of Federal, State, and local officials will be contacted.

3.1 Existing Technical Literature

The New Jersey Pinelands Comprehensive Management Plan and the Ocean County Comprehensive Master Plan provided the initial land use background.

3.2 Discussions with Local Officials

Local offices that were contacted as part of the initial data collection effort include the following:

- Ocean County Planning Board
- Monmouth County Planning Board
- Burlington County Planning Board
- Public Affairs Office, Fort Dix
- Public Affairs Office, McGuire Air Force Base
- Public Affairs Office, Naval Air and Engineering Center
- State Planning Commission
- Region 4, New Jersey Department of Transportation, Division of Roads and Highways
- County Engineer, Supervisor of, Ocean County
- Principal Traffic Analyst, Ocean County Department of Transportation
- New Jersey State National Guard.

In addition to those initial contacts listed above, further information was gathered from the following sources:

- New Jersey Agricultural Statistics Service
- New Jersey Department of Agriculture
- New Jersey Division of Fish, Game, and Wildlife
- New Jersey Department of Labor, State Data Center
- Ocean County Extension Service.

Local planning and public works officials, planning consultants for local towns and Federal, State, and county officials were contacted as necessary to provide information in addition to that received from the contacts listed above.

4.0 METHODS FOR ASSESSING EXISTING BASELINE CONDITIONS

Data concerning residential and commercial development were collected in addition to statistics regarding agricultural production. This information was collected from county- and State-level agencies.

These data were reviewed to determine historical patterns of development and potential future land uses. Current agricultural, conservation, recreation, commercial, and residential uses were evaluated in terms of approved general development plans to predict future development pressures and impacts on the area.

5.0 METHODS FOR ASSESSING THE LAND USE IMPACTS

Land use impacts from the five alternatives for the BOMARC Missile Site were developed. Impacts that would result from implementation of this alternative were evaluated in the context of the planning horizons that would be affected. The current and future horizons were evaluated. Current is defined as the planning horizons specified in the land use plans that have been adapted by the jurisdictions adjacent to the site. Future is defined as the timeframe for which comprehensive plans have not been developed. Impacts are assessed based on the potential that an alternative would conflict with current land use plans or could conflict with future land use plans.

The Level of Impact was assigned qualitatively based on whether implementation of the alternative would conflict with land uses or land use plans of the adjacent jurisdictions. Negligible was used if there did not appear to be a potential for conflict. Low was used if there was some potential for conflict. Moderate was used if there was a definite potential for conflict. High was used if there was certain to be conflict.

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Appendix 3-6

Transportation Methodology Development Report

May 1992

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TABLE OF CONTENTS

LIST OF FIGURES

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1.0 INTRODUCTION

This document was prepared to support the analysis provided in the Environmental Impact Statement (EIS). The objective of this document is to supplement the EIS by providing the reader with additional information to augment and support the analysis provided in the EIS.

This Transportation Methodology Development Report (TMDR) explains the methods used to obtain the data discussed in the transportation portion of the Environmental Impact Analysis Process for addressing the low-level radioactive contamination at the BOMARC Missile Site. The scope of this TMDR includes:

- A description of the existing roadway network, traffic volumes and other parameters.
- An identification of data sources based on a preliminary review of potential impacts. The extent of this data collection will be dependent upon the ultimate action taken.
- The methodology for assessing the baseline condition (existing traffic volumes, maintenance procedures, accident rates, etc.) and potential impacts is outlined. This includes the identification of impacts criteria and significance criteria.

2.0 EXISTING TRAFFIC PATTERNS AND ROAD NETWORK CONDITIONS

A field visit was conducted to describe the road conditions, the type of traffic, speeds, the location of the BOMARC gate in proximity to the roadway, and the access and egress points along Route 539.

Access to the BOMARC Missile Site is from Ocean County Route 539. Ocean County is responsible for maintenance of this roadway. The county also maintains two roadways located north of the site, Routes 528 and 537. Route 70 is a State maintained roadway located south of the site. Route 539 cuts the site off from the rest of the Fort Dix complex. There is no direct access to the site from the Lakehurst Navel Engineering and Aeronautic Center. Figure 2-1 shows the location of these roadways.

Several jurisdictions (cities, townships, counties, and the state) maintain the roads in the primary Region of Influence (ROI). The functional roadway hierarchy follows the order of the jurisdictions listed, with city streets (locals and collectors) being the lowest functional class in the primary ROI and the state and county maintained roads being the principal arterials. Since state and county routes carry the majority of traffic in and around the site, they are the focus of the baseline description.

County-maintained roads are the predominant traffic arteries in the primary ROI. In New Jersey, the county road network consists of segments which may be local to one county or part of a longer road spanning several counties. Counties generally assign a local route number to

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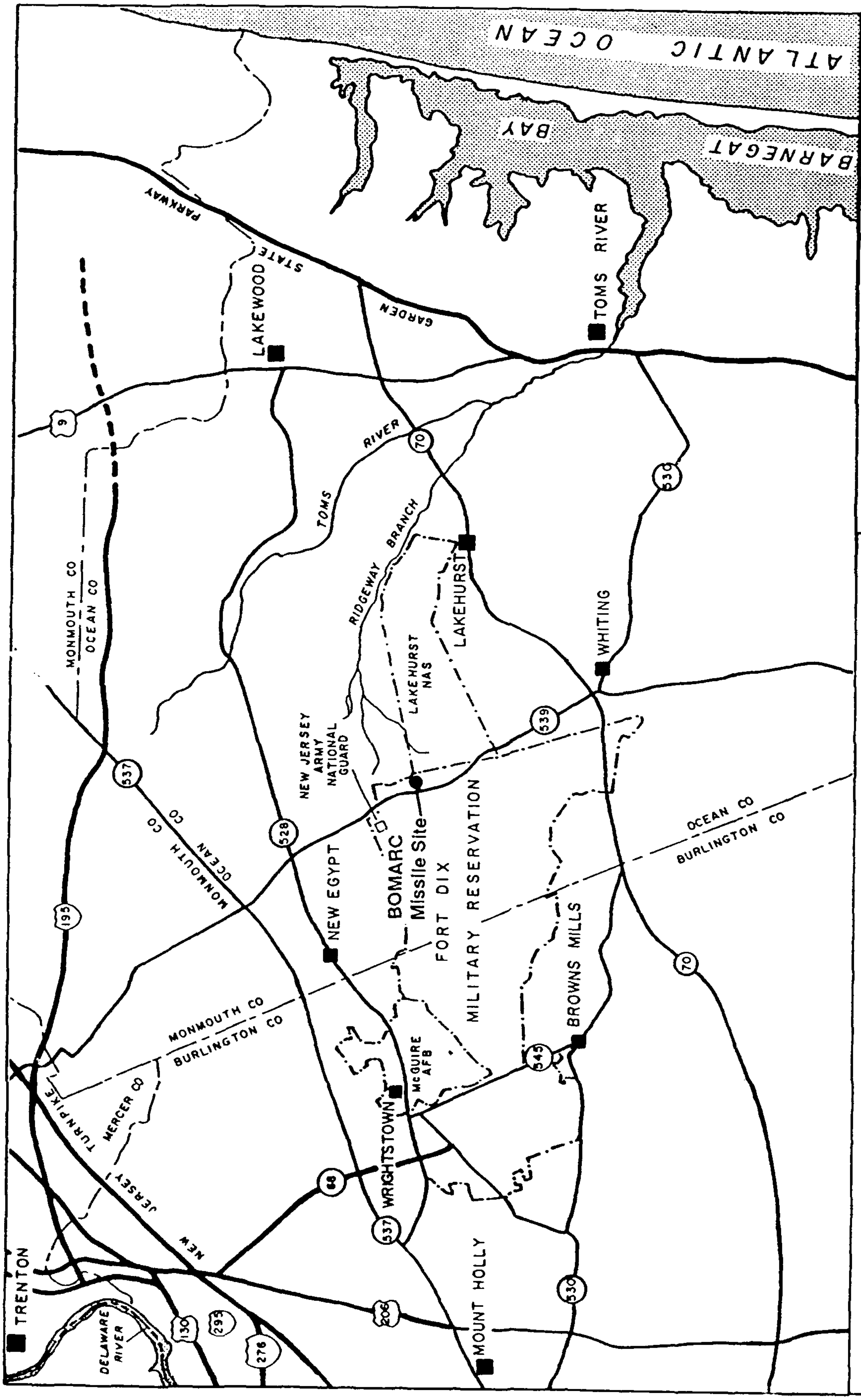

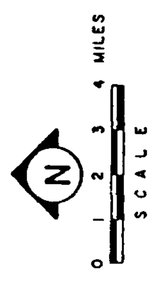

FIGURE 2-1

ROAD MAP FOR THE VICINITY

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each of their roads. The state has assigned numbers to many county-maintained roads to provide consistent route designations across county boundaries for the latter category. For clarity, these route numbers are used herein in lieu of the individual county designations.

The major highway network in the primary ROI consists of one state highway, Route 70; and portions of county Routes 539, 528, 571, 547, 530, 545; Ocean County Route 42; and Burlington County Route 616. Figure 3-19 shows the network. Ocean County Route 539 serves the BOMARC Missile Site. The other roads either feed traffic into Route 539 or comprise the shortest practical alternate Route around the segment of Route 539 serving the base. Each of these roads is discussed in the following sections.

Initial inquiries indicated that the Average Annual Daily Traffic (AADT) counts on State Route 70 at the intersection with Route 539 in Manchester Township was 8,100 vehicles per day on an average basis in 1985. The County took a June/July reading at the intersection of Route 539 and Route 528 in 1988. Daily traffic volumes on Route 539 were 5,600 vehicles on the south side of the intersection, and 9,500 vehicles on the north side of the intersection. The east side of Route 528 had 3,500 vehicles daily while the west side had 3,900 vehicles.

Data to characterize the roadways was obtained from the counties, the state of New Jersey, and field observations. In general, hard data on the operating characteristics of the roads are sparse. In the evaluation that follows, Route 539 received the greatest attention because of its close proximity to the BOMARC Missile Site. The other roads are described because of their proximity to the site.

2.1 Route 539

Route 539 is the road adjacent to the BOMARC Missile Site. This section is part of an overall Route running southeast from Hightstown through portions of Mercer, Monmouth, and Ocean counties to Tuckerton on the Atlantic coast. Route 539 intersects Interstate-195 just east of Trenton and the Garden State Parkway just north of Tuckerton. There are no significant population centers along the route.

The portion of Route 539 within the primary ROI extends between state Route 70 and Ocean County Route 528, a total distance of 9.7 miles. The BOMARC Missile Site is located about 4 miles south of the intersection of Routes 528 and 539 near highway milepost 31. The base has four entrances on Route 539 spaced over a total distance of 0.4 miles. The main base entrance is the most southerly one.

Within the ROI, Route 539 is a two-lane, rural highway. The road is flat and has many straight sections and broad curves. Major intersections are located at Route 528 and state Route 70. Both intersections have traffic signals. Other intersections on Route 539 within the primary ROI include Horicon Avenue, Long Swamp Road, and Colliers Mills Road. Route 539 is the major road in all of these intersections. Ocean County has recently overlaid the surface to provide adequate thickness for 80,000-pound trucks. Based upon a visual survey, the condition of the road surface within the ROI is excellent, with little or no distress visible. Ocean County has no future plans for additional surfacing work on the road. The only significant structures on Route 539 within the ROI are short deck spans over the forks of Hurricane Branch.

Route 539 serves as a principal through route within Ocean County. The road does not appear, however, to consistently originate or terminate any significant volume of traffic within the ROI. Land use is rural for most of the length, with some single-family housing along the northern three miles. There is a New Jersey Army National Guard training center 0.4 miles north of the BOMARC Missile Site. The road appears to be an artery for traffic between the urbanized area around Trenton and the developing coastal area. It also serves as part of one access route to the Fort Dix/McGuire AFB complex for staff living in southeast Ocean County. In addition, the road can be used to travel to the Colliers Mills Wildlife Management Area (WMA) and the New Egypt Raceway from points south.

Discussions with the Ocean County Engineering Department revealed that detailed traffic origin/destination studies for traffic using Route 539 had not been conducted. Because of the low intensity of land use along the road within the primary ROI, there is no formal traffic counting program. The engineering staff felt that the road experienced significant seasonal variation in traffic, principally due to its use during the summer months as a route to the coast. During field observations, heavy trucks appeared to be a significant part of the traffic flow. The County engineering staff indicated that this was an important traffic flow in the region.

Results of several counts conducted for various purposes during 1988 were obtained from the county. To supplement the count data provided by the County, spot counts were conducted during two weekday periods at milepost 31. The count data at the location one mile north of Route 528 were obtained over the three day period May 20-22, 1988. The volumes recorded were 8,476 on the first day, 9,610 on the second day, and 10,431 on the third day, for an average of 9,506 per day. The weekday peak hours started at 7:00 am (552 vehicles) and 5:00 pm (763 vehicles). The weekend traffic was higher than the weekday traffic. The Saturday count showed a single morning peak hour, starting at 10:00 am, during which 1,608 vehicles passed the count station. Sunday showed a similar pattern.

South of Route 528, within the primary ROI, the count data were obtained over a 48-hour period from May 23-25, 1988. It appears that the actual traffic volume count is around 5,900 vehicles. The peak hours during these weekday periods began at 8:00 am (564 vehicles average) and 5:00 pm (530 vehicles average).

Spot vehicle counts were conducted at milepost 31 on November 15, 1989 and on November 17, 1989. The spot count revealed a directional split of 69 percent southbound verses 31 percent northbound during the afternoon peak hour. Trucks comprised 3.7 percent of the vehicle flow. During the off-peak hours of the spot counts, trucks comprised 12.3 percent of the flow.

The Highway Capacity Manual provides criteria for evaluating the level of service for highways. Based upon the data gathered on the highway geometry, an assumed design speed of 60 mph, and the count data for the peak hours, the level of service (LOS) during the peak hour for the section of Route 539 adjacent to the BOMARC Missile Site is an LOS 'C'.

The maximum service flow rate of the road under LOS 'C' is 767 vehicles per hour (vph), so additional capacity is available. Thc traffic stream consisted of discrete groups of vehicles, or platoons, sometimes containing as many as one dozen cars and trucks. Passing was somewhat inhibited by the traffic stream, although travel speeds remained high. The service flow rate for

the next lowest LOS, 'D', is 1,149 vph. Based upon the data, the section north of Route 528 appears to fall within this category during the weekend peak.

2.2 State Route 70

State Route 70 is the only state highway within the primary ROI. The surface of Route 70 is asphalt cement concrete, which is generally in good condition with no significant surface distresses observed. Route 70 extends from Camden to Pt. Pleasant on the Atlantic coast, via Camden, Burlington, and Ocean counties. Lakehurst is the only major town between these points. The highway is part of the Federal Aid Primary system. The section within the ROI lies between the intersections of Route 530 near Pemberton and Route 547 in Lakehurst, a distance of 11 miles. Route 539 roughly bisects this segment.

There are few intersections on Route 70 within the primary ROI. The intersection of Route 70 and Route 539 is the major intersection. This intersection is fully signalized, with the state maintaining the signal system. A traffic circle is located on Route 70 on the west side of Lakehurst. This circle provides access to several local roads serving the Lakehurst community. From the traffic circle to the intersection with Route 547, a developed area extends along Route 70 for about 2.5 miles. The intersection with Route 547 is signalized.

Traffic does not appear to be high on the rural section of Route 70. During 1984 and 1985, the New Jersey Department of Transportation installed a continuous count station in Manchester Township. This station yielded an AADT of 7,900 vehicles for 1984, and 9,300 vehicles for 1985. Field observation of this portion of Route 70 identified no significant traffic problems, however. Flow characteristics were very similar to those of Route 539. The level-of-service on the roadway is estimated to be 'C' during the peak period based, upon observation and comparison with Route 539.

Within Lakehurst, Route 70 carries much local traffic. No specific count data were available for this section. The daily counts are no doubt higher than those measured on the rural section of the road. Because of the urban characteristics, intersection capacity, rather than link capacity, will govern service levels. Without much more data, however, service levels could not be computed.

2.3 Route 547

Route 547 is an Ocean County Route connecting the towns of Lakehurst and Neptune. In the ROI, Route 547 extends from Route 70 to Route 571, a length of about 1.7 miles. The section of interest serves Lakehurst Naval Air and Engineering Center (NAEC). The southwestern end in Lakehurst is urban in nature, but the remainder of the road is rural in character. Both the intersection with Route 70 and the intersection with Route 571 are signalized.

Route 547 is a two-lane, nondivided highway. Lakehurst NAEC is located about halfway between Route 70 and Route 571. Within the primary ROI, Route 547 has minimal hills or curves and no bridges or other structures. Pavement conditions are adequate. The county had no recent traffic count data for Route 547. Limited field observations along Route 547 indicated no abnormal operational problems.

2.4 Route 571

Route 571 runs from the vicinity of Bay Shore, just east of Toms River, to Princeton, through Ocean, Monmouth, and Mercer counties. Within the primary ROI, this route connects Routes 547 and 528. The length is about 6.9 miles.

Route 571 is a two-lane rural minor arterial. The road is level and consists of stretches of roadway broken by short curves. Surface conditions are generally fair, although there are some localized areas of distress. The traffic stream on Route 571 is similar to that of Route 539. There is a significant heavy truck volume. County engineering staff indicated that the road carries a significant commuter volume from the populated areas of Ocean County toward Trenton and Princeton. It also appears likely that the road carries seasonal recreational traffic toward coastal communities.

As with the other county roads in the primary ROI, traffic data are limited. The most recent available traffic counts were taken in 1980 and 1981. The counts at this time ranged from 3,300 to 4,200 vehicles per day (vpd). No adjustments such as peak hour factors are available. Using factors derived for Route 539, peak hour volumes appear to be between 400 and 600 vehicles, which would indicate an LOS of 'C'. Off-peak field observations revealed higher service levels and generally smooth traffic flow.

2.5 Route 528

Route 528 extends from Mantoloking on the Atlantic coast to Bordentown, just south of Trenton. The road lies in Monmouth and Ocean counties. The section within the primary ROI lies between New Egypt and the intersection of Route 571 in Cassville, a distance of about eight miles. Route 528 intersects Route 539 about three miles east of New Egypt. Land use is primarily rural along the route, although the there are stretches of single-family housing. The road is relatively straight, with some short curves on the western end. Hills are minimal. Major intersections occur at Routes 539 and 571. Both of these are signalized. Surface conditions are fair to poor. Traffic counts taken in 1988 near the intersection of Route 539 indicate daily volume of about 3,900 vehicles. The counts indicate a LOS in the peak hour of perhaps 'B' or 'C'. However, discussions with county engineers determined that utilization of Route 528 is highly seasonal.

2.6 Stump Tavern Road (County Route 42)

Stump Tavern Road provides a three-mile long connection between Routes 571 and 528. The road borders the Colliers Mills WMA, and is wooded on the west side. Land along the east side has a mixture of woods and single-family homes. The road alignment is relatively straight and level. The road is surfaced with asphalt which is in poor condition. The daily traffic count for Stump Tavern Road, taken in 1981, yielded a count of 816 vehicles, a relatively small number.

2.7 Route 530

Route 530 connects South Toms River in Ocean County with Pemberton in Burlington County. The section within the ROI lies between Route 70 and the intersection with Route 545 in Browns

Mills, a distance of about five miles. Near Route 70 land along Route 530 is rural. As the road approaches Browns Mills, the predominant land use changes to single-family housing and light retail. The road alignment is relatively level, but there are numerous curves. The asphalt roadway surface is generally in fair condition. The road has only a few minor bridges.

Burlington County provided count volumes of 3,000 vpd (1989) near the Route 70 intersection and 15,500 vpd (1988) near the intersection of Route 545 in Browns Mills. Observed off-peak service levels appeared to fall into the 'B' range. The close proximity of the military installations likely causes sharp peaks, so service levels may be significantly lower at times.

2.8 Route 545

Route 545 connects Browns Mills with Bordentown. The section within the ROI lies between Route 530 in Browns Mills and the intersection with Route 616 in Wrightstown, a distance of about five miles. The road passes through Fort Dix and McGuire AFB, receiving heavy local base traffic. Within the primary ROI, land uses adjacent to the road include the military bases and the commercial and residential areas around Browns Mills and Wrightstown.

The road alignment is generally straight; however, there are some curves. The asphalt roadway surface is in fair condition. Traffic related to the military installations seems to account for a high percentage of the use of Route 545 in the primary ROI. Burlington County provided 1988 count volumes of 9,600 vpd in Browns Mills, 12,900 vpd near the bases, and 20,300 vpd in Wrightstown near the intersection of Route 616.

2.9 Burlington County Route 616

Route 616 connects Route 545 in Wrightstown with Route 528 in New Egypt, a distance of about 5.5 miles. The road serves the main gate of McGuire AFB. Within the primary ROI, land uses adjacent to the road include the military base and the commercial and residential areas around Wrightstown. Outside of urban areas, the road alignment is essentially straight and level. The asphalt roadway surface is in fair condition. Burlington County provided 1989 count volumes ranging from a high of 9,600 vpd west of the main gate of McGuire AFB to 4,900 vpd west of New Egypt. Peak-hour LOS, truck volumes, and other traffic indexes are unknown.

3.0 DATA SOURCE IDENTIFICATION

Traffic analyses are dependent upon local comprehensive plans, observed traffic volumes, the condition of the existing network, and a number of other factors. Because the BOMARC Missile Site is located in the Pinelands National Preserve, adjacent to three major Federal installations and a Wildlife Management Area, a number of Federal and State officials in addition to local officials were contacted.

3.1 Existing Technical Literature

New Jersey's Pinelands Comprehensive Management Plan and the Ocean County Comprehensive Master Plan provided the initial background and contained extensive bibliographies. State and County traffic files and other relevant reports were also reviewed.

3.2 Site Specific Studies

A field visit was conducted to describe road conditions, the type of traffic, speeds, the location of the BOMARC gate in proximity to the roadway, and the orientation condition of access and egress points along Route 539. A trip generation survey and an independent traffic volume count were conducted in order to determine the impacts of a detour or reduced access along Route 539.

3.3 Discussions with Local Officials

Land use and land development affect the local traffic pattern; therefore, a number of local officials must be contacted to assess the impacts of altering the traffic pattern on Route 539.

The following officials were contacted as part of the data collection effort:

- Alan Avery, Assistant Director of Planning, Ocean County Planning Board Staff
- Frank Donnahue, Principal Planner, Manchester County Planning Board Staff
- Thomas Jaggard, Planning Engineering, Burlington County Planning Board Staff
- Richard Dowly, Public Affairs Officer, Fort Dix
- Captain Debra Bosik, Public Affairs Officer and Project Liaison, McGuire Air Force Base
- Frank Monterelli, Public Affairs Officer, Naval Aeronautic and Engineering Center
- Jim Shue, Area Planning Manager, State Development and Redevelopment Authority
- Michael Newman, Area Planning Manager, State Development and Redevelopment Authority
- Charles Miller, Principal Engineer for Region 4, New Jersey Department of Transportation, Division of Roads and Highways
- Richard Lane, County Engineer, Supervisor of Roads for Ocean County
- Dennis Madebach, Principal Traffic Analyst, Ocean County Department of Transportation

- Sergeant Shenko, Hazardous Waste Specialist, Unit Training Equipment Site (UTES), New Jersey State National Guard

- James Quinn, County Engineer, Burlington County

- Joe Pavlak, Traffic Engineer, Burlington County

- Curt Aufscheider, Travel Projections Unit, New Jersey Department of Transportation

- Jim Panzitta, Traffic Counts, New Jersey Department of Transportation.

4.0 METHODS FOR ASSESSING EXISTING BASELINE CONDITIONS

The initial effort for the impact analysis was focused on data collection in order to characterize the existing road facilities in the primary ROI. Existing analyses were utilized to characterize the transportation network outside the primary ROI. The following list identifies items that were obtained from the Ocean County and/or New Jersey Departments of Transportation:

- AADT counts
- Vehicles classifications
- Peak factors for traffic
- Accident statistics
- Physical condition of existing pavement
- Geometric data.

An independent traffic volume count was conducted in order to determine the impacts of a detour or reduced access along Route 539.

4.1 Traffic Pattern

State Highway, County Roadway and other maps were consulted. Access and egress into the site and "curb cuts" or access points onto Route 539 were reviewed.

4.2 Traffic Volumes

AADT counts for local roads were obtained. Proposed repairs and reconstruction schedules were consulted. This data is available though the County and the State Departments of Transportation. The number of counts and their applicability to present operating conditions was considered to assess baseline conditions of highway transportation.

5.0 METHODS FOR ASSESSING THE TRANSPORTATION IMPACTS

There are a number of environmental impact statements and other documents that address potential impacts resulting from transportation of radioactive wastes. Those analyses were reviewed and the impact analyses conducted in them was incorporated by reference into this EIS. The analysis for this EIS focused on the primary ROI immediately proximate to the site.

An assessment of the impacts upon the level of service for the roadways in the vicinity of the BOMARC Missile Site was conducted. A decrease in the level of service is possible if one or more of the following factors occur:

- The amount of time spent at an intersection increases significantly; an increase from 30 seconds to 60 seconds would be considered significant
- An intersection does not clear during a complete signal change
- The traffic speed decreases more than five miles per hour
- The number and type of traffic accidents increases significantly.

6.0 LEVELS OF IMPACT CRITERIA

The levels of impact (LOI) criteria for transportation near the BOMARC Missile Site involve the access along Route 539. Access to Route 539 might be altered for the following reasons:

- The potential for a radiation dose due to site activities is present along the roadway, putting travelers at risk
- A portion of the roadway is closed as part of the clean up because contaminated material is found to be in or along the roadbed
- Heavy machinery must enter or leave the site on a regular basis. This could lead to a significant increase in traffic volume and a slowing of roadway speed (travel time).

The LOI was assessed according to the following scenarios:

- Negligible Impact - The number and type of vehicles entering the site increases but does not change significantly and Route 539 is not impacted
- Low Impact - The number and type of vehicles entering the site increases but does not significantly alter the AADT or travel speeds on Route 539
- Moderate Impact - The number and type of vehicles entering and leaving the site increases or a portion of Route 539 is temporarily closed; this would reduce the observed speeds on Route 539 and/or results in increased AADT on adjacent roadways
- High Impact - Route 539 is permanently closed, resulting in the relocation of the access to the National Guard Facility and increased AADT on adjacent roadways as well as increased travel time for local commuters.

7.0 SIGNIFICANCE CRITERIA

The significance of an impact is determined by evaluating its context and intensity as required under the Council of Environmental Quality (CEQ) regulations (40 Code of Federal Regulations (CFR) 1508.27). According to CEQ regulations, there are ten items that should be considered in evaluating the significance of an impact:

- Beneficial as well as adverse impacts
- Effect on public health and safety
- Unique (e.g., historic, scenic, etc.) features of the area
- Effects on the environment that are likely to be controversial
- Effects on the environment that are uncertain or unknown
- Precedent setting actions with significant impacts
- Actions that contribute to significant cumulative impacts
- Adverse impacts on scientific, cultural or historic places
- Adverse effects upon endangered species
- Actions that violate Federal, state or local laws.

In addition to the CEQ criteria, the following considerations were judged as being applicable and appropriate in evaluating the significance of the impacts that would occur to local traffic patterns as a result of the actions taken to address the levels of radioactivity observed around the BOMARC Missile Site.

- The re-routing of the traffic currently using Route 539 and its affect on local business

- The re-routing of the traffic currently using Route 539, altering the local pattern of growth and development

- A permanent or temporary detour around Route 539 resulting in a significant economic or personal hardship for local residents

- Increased truck traffic increasing the frequency of road repairs on Route 539 and the cost of this required maintenance.

The conclusions of the other documents (see Section 3.7.1 of the EIS) that evaluated potential significance of impacts resulting from the transport of radioactive wastes were incorporated into the EIS.

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Appendix 3-7

Demographic Methodology Development Report

May 1992

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1.0 INTRODUCTION

This document was prepared to support the analysis provided in the Environmental Impact Statement (EIS). The objective of this document is to supplement the EIS by providing the reader with information to augment and support the analysis provided in the EIS.

This Methodology Development Report (MDR) includes discussions of methods used to provide:

- Descriptions of existing and future population, including a discussion of local and regional development issues.
- Identification of data sources based on a preliminary review of potential impacts.
- A description of the methodology to be used for assessing the baseline condition (the existing demographic pattern) as well as future conditions.

2.0 CURRENT POPULATION

Current population data for 1980 were provided for areas of New Jersey, New York and Pennsylvania within a 50-mile radius of the BOMARC Missile Site. Local population for 1980 (within a five mile radius) was reviewed by census tract. Population projections within 50 miles were provided for the year 1995.

3.0 DATA SOURCE IDENTIFICATION

Demographic data sources include existing literature and local officials as discussed below.

3.1 Existing Technical Literature

Population information was gathered from the State Data Centers of New Jersey, New York and Pennsylvania and from the U.S. Census Bureau. This included population projections, as well as descriptions of methods used by the states in developing these figures.

3.1.1 County Level Projections

County level projections were obtained from the state data centers of New Jersey, New York and Pennsylvania. The following describes the type of methodology used by each state in formulating these projections and the information available in terms of years projected.

3.1.1.1 New Jersey

Population projections for New Jersey are prepared by the New Jersey Department of Labor, Division of Labor Market and Demographic Research, State Data Center. New Jersey uses an Economic-Demographic Model for projections. This model is based on standard demographic projection procedures (cohort-component method), but assumes employment growth as the major impact on migration. Therefore, the model is driven by labor demand. In terms of this model,

state population and employment growth are constrained after the year 2000 in relation to labor supply constraints at the national level. New Jersey projections are available through the year 2030.

3.1.1.2 New York

Population projections for New York are prepared by the New York State Department of Commerce, State Data Center. New York uses a basic cohort-component model. Projections go forward by five year age/sex cohorts. The model recognizes three components of change (1) fertility, (2) mortality, and (3) migration. Each county is projected independently of other counties, and no attempt is made to control county figures to meet a predetermined state total. New York projections are available for a 30-year period through the year 2010 and use the 1980 census population as a base.

3.1.1.3 Pennsylvania

Population projections for Pennsylvania are prepared by the Pennsylvania State Data Center, Institute of State and Regional Affairs, the Pennsylvania State University at Harrisburg. Pennsylvania also uses a cohort-component demographic projection model. Basic population is projected in five year segments. Natural increases in population are derived by applying fertility rates to females of childbearing age. Population projections for all groups are adjusted for projected net migration. Pennsylvania projections are available through the year 2000, and are based on 1980 Census figures.

3.1.2 Tract-Level Projections

The first five mile radius from the BOMARC Missile Site contains lands that are located entirely within Ocean County. For projection purposes in this smaller area, figures were used from census tract information prepared by CACI. CACI is a private company that prepares and sells demographic data. The company compiles demographic profiles beginning with the 1970 U.S. Census, from which updates and projections are prepared by county and census tract. An annual post-census estimate series produced jointly by the U.S. Census Bureau and the states through the Federal-State Cooperative Program for Population Estimates provides additional data. CACI's estimates are extrapolated to the year 2000 with the addition of population projections by county.

Census tract projections by CACI are derived from a combination of models including share, shift-share, exponential, and linear change. The former two models are basically ratio methods. The latter two methods provide avenues for accounting for sub-county variations in the extrapolation process. The results of these four methods are averaged. Although this averaging does not guarantee the least amount of error, it does tend to discount extremely high or low totals (known as outliers).

The counties to be evaluated for the project are identified based on their location within the 50-mile radius Region of Influence (ROI) of the BOMARC Missile Site. A map of these counties are then overlayed with a series of concentric circles. These circles allowed the area to be viewed in annuli (rings) of a specified size. In this instance, the rings are selected at one, two,

three, four, five, ten, twenty, thirty, forty, and fifty miles from the BOMARC Missile Site (center). This results in areas that reflect designated distances in miles from the BOMARC Missile Site (selected as 0-1, 1-2, 2-3, 3-4, 4-5, 5-10, 10-20, 20-30, 30-40, and 40-50).

These annuli (rings) are further divided into a series of sectors based on the sixteen major compass points. This provides a series of 160 independent areas (annular sectors) that could conceivably contain land areas affected by this site study. Certain sectors contain all, or mostly water.

Using the map described, county lands are measured by annular sector, and population is assigned to each sector assuming a homogeneous distribution within each county.

The area within five miles of the site, as mentioned, is located within Ocean County. Projections for this area are evaluated on a tract basis. To project population for the remainder of Ocean County, the population in the five mile area was subtracted from the rest of the county figures and that number is split proportionately, as with other counties.

Census tract data from CACI are available for the year 1994. In order to align the tract-level population levels with the 1995 county-level projections provided by the states, it is necessary to update the CACI numbers. This is accomplished by dividing the 1994 Ocean County projections into the 1995 New Jersey statewide projections to determine a multiplier. An increment of just under 2.8 percent is calculated as appropriate to adjust for 1995 Ocean County census tract numbers and each tract's population count is modified accordingly.

Following adjustment of tract projections to 1995, the resulting totals are reviewed in light of land use patterns in the area. Through discussions with local officials, it is determined that the portion of Ocean County Tract 190 within five miles of the BOMARC Missile Site contained no residential population. Group quarters located at Fort Dix in Tract 190 at the time of the 1980 Census are now located in Burlington County. To reflect this, the 1970 group quarters population from Tract 190 is added to Burlington County's population. The county population is then split proportionately, as in other counties.

3.2 Discussions with Local Officials

Land use and land development is the driving force behind most population growth. In order to assess the levels of future population for risk analysis, local planning officials were contacted.

The following local offices were contacted as part of the initial data collection effort:

Ocean County Planning Board
Monmouth County Planning Board
Burlington County Planning Board
Public Affairs Office, Fort Dix
Public Affairs Office, McGuire AFB
Public Affairs Office, Naval Air and Engineering Center
State Planning Commission
Pinelands Commission.

Further information was gathered from the following sources:

Department of Engineering and Housing, Fort Dix
Department of Civil Engineering, McGuire AFB
New Jersey Division of Fish, Game and Wildlife
New Jersey Department of Labor, State Data Center
New York Department of Commerce, State Data Center
Pennsylvania Department of Commerce, State Data Center.

Local planning and public works officials, planning consultants for the local towns, as well as Federal, State and County officials were contacted as necessary to provide information in addition to that received from the contacts listed above.

4.0 METHODS FOR ASSESSING EXISTING BASELINE CONDITIONS

Along with U.S. Census data describing existing population levels, state population projections by county and CACI forecasts by Census tract for Ocean County were collected.

Appendix 3-8

Public Health Hazard Assessment: Methods Used to Assess Potential Radiological Impacts

May 1992

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1.0 INTRODUCTION

This appendix was prepared to support the analysis provided in the Environmental Impact Statement (EIS). The objective of the appendix is to supplement the EIS by providing the reader with information to augment and support the analysis provided in the EIS. Section 1 contains a brief background to the radiological hazards presented by the radioactive contamination at the Boeing Missile Aeronautical Research Center (BOMARC) site. The mechanisms by which radioactivity could potentially be released to the surrounding environment from the BOMARC Missile Site are presented in Section 2.0 of this appendix, and the methods for assessing radiation dose from these releases are discussed in Section 3.0.

Assessment of potential radiological impacts requires the use of computerized models to describe the site conditions, the movement of radioactivity, the effect of human activities, and the resulting radiation doses. The models chosen for this assessment are designed specifically for situations such as those occurring at the BOMARC Missile Site. They include all site characteristics and exposure pathways relevant to sites with surface soils that are contaminated with radioactivity, including transuranic radionuclides. Potential off-site population doses have been evaluated using the GENII computer code as discussed in Section 3.1 of this Appendix. Doses to potential on-site intruders have been evaluated using the RESRAD code as discussed in Section 3.2.

These models require, as input, parameters that describe a variety of site characteristics. For this assessment, values specific to the BOMARC Missile Site have been used wherever possible. Where site-specific data are not available the default values have been used. These default values have been provided by the developers of the models after extensive review of the environmental literature. They represent generic conditions and are intended to be conservative, that is, they tend to over-estimate potential radiation dose.

In order to assess the potential impacts from each of the EIS Alternatives, many assumptions were made so that processes at the site could be modeled. The assumptions are based on site-specific characteristics to the extent possible. However, some assumptions are generic, and, in order to bound potential impacts, most assumptions are conservative (i.e., tend to maximize any detriment). Some of the uncertainties in dose and risk assessments are discussed in this Appendix (Section 1.3). The modeling assumptions made in this assessment are intended only for the purposes of radiological assessment of the BOMARC EIS Alternatives.

1.1 Radiological Hazards Associated with Plutonium and Americium

In general, the calculation of radiation doses to an individual is based on the exposure pathways by which each radionuclide causes irradiation. Four pathways are considered in this analysis:

1. External exposure from immersion in a radioactive cloud.
2. External exposure from radioactive material on the ground.
3. Internal dose from inhalation of radioactive material.
4. Internal dose from ingestion of contaminated foods, soil, and water.

To present a significant hazard from external exposure, a radionuclide must emit penetrating radiation in the form of a photon or energetic beta particle. Among the radionuclides of concern at the BOMARC Missile Site, only ^{241}Am has a photon emission sufficient to pose a potential external exposure hazard.

Internal dose from ingestion of contaminated food depends on the uptake of each radionuclide into foods and subsequent uptake by the human body. All actinides are poorly taken up by plants, animals, and people. Consequently, while some potential exists for radiation dose from ingestion of contaminated food, this is not the dominant pathway for plutonium and americium. Intake of contaminated groundwater is another potential source of radiological dose from plutonium. However, plutonium and americium are relatively insoluble in groundwater, and are not readily transported via groundwater movement. Finally, direct ingestion of contaminated soil is a potential source of radiological dose from plutonium. Ingestion of soil occurs more frequently with infants and children than with adults, but it can be an important dose contributor.

The pathway of primary concern for plutonium and americium is inhalation of contaminated particles. This is a consequence of three factors. First, these radionuclides are alpha particle emitters. Alpha particles have very short ranges in tissue and deposit their energy in small volumes. Second, the chemically inert actinide oxides remain in the lung for long periods of time. Finally, radioactive contamination at the BOMARC Missile Site exists in a form that is likely to produce respirable particles during clean-up activities.

1.2 Radiation Dose and Risk

The measure of radiological hazard calculated in this assessment is in 50-year integrated dose commitments reported in units of rem, often referred to as "dose" for brevity. These are calculated for each of several organs of the body for each radionuclide. Because different radionuclides irradiate different organs and tissues, a method that expresses the total radiation risk to an individual is used. The International Commission on Radiological Protection (ICRP) has developed a model to equate the sum of the doses received by individual organs and body tissues to a single index of risk, the effective dose equivalent (EDE). The ICRP models for organ committed dose equivalents and effective dose commitments (ICRP, 1977; ICRP, 1979) have been used to develop a set of dose conversion factors that relate: (1) concentration (in the air and on the ground) to external dose rates; and (2) intake (by inhalation and ingestion) to internal dose. These dose conversion factors are presented in Table 1-1.

Health effects resulting from low doses of radiation are of a statistical nature. Knowledge of the delayed effects of low doses of radiation is necessarily indirect, because the incidence is too low to be observed against the much higher background incidence of similar effects from other causes. Hence, a relationship between health effect and radiation dose can only be estimated, based on observations made at much higher exposure levels, where effects have been observed in humans, and on animals through carefully conducted experiments. In the range of doses under consideration for the BOMARC Missile Site the incidence of resulting health effects is very small. There have been no direct measurements of increased cancer incidence rates for low-level radiation exposures. Consequently, these estimates are relevant only to the average collective dose received by large populations of individuals and not to estimates of doses to individuals.

Table 1-1
Dose Conversion Factors for Plutonium and Americium

Radionuclide	Effective Dose Equivalent	Bone Surface	Liver	Lung
External Dose Conversion Factors[a]:				
Air immersion (mrem/yr per μCi/m^3)				
^{239}Pu	4.1×10^{-1}	4.0×10^{-1}	2.0×10^{-1}	2.4×10^{-1}
^{241}Am	9.5×10^{1}	1.3×10^{2}	6.2×10^{1}	6.9×10^{1}
Ground Surface (mrem/yr per μCi/m^2)				
^{239}Pu	3.8×10^{-2}	1.5×10^{-2}	4.8×10^{-3}	8.9×10^{-3}
^{241}Am	3.0×10^{0}	3.7×10^{2}	1.8×10^{0}	2.0×10^{0}
Internal Dose Conversion Factors[b]:				
Inhalation (mrem/μCi)				
^{239}Pu	5.1×10^{5}	9.3×10^{6}	2.0×10^{6}	1.2×10^{6}
^{241}Am	5.2×10^{5}	9.3×10^{6}	2.0×10^{6}	1.2×10^{6}
Ingestion (mrem/μCi)				
^{239}Pu	4.3×10^{3}	7.8×10^{4}	1.6×10^{4}	0
^{241}Am	4.5×10^{3}	8.1×10^{4}	1.7×10^{4}	0

a. Source: DOE (1988a).
b. Source: DOE (1988b). Aerosol class or gastrointestinal tract uptake fraction yielding the highest dose per unit were used.

Because expected releases of radioactive material from the BOMARC Missile Site would be small and the projected radiation dose to any individual is small, the only effects considered are long-delayed somatic (cellular) effects. Acute radiation effects require exposures many orders of magnitude greater than those projected for BOMARC Missile Site remediation. The delayed effects considered in this assessment are potential excess fatal cancers of the lung, bone, and liver.

For the BOMARC Missile Site, the major concerns are associated with radiation dose to the lung, liver, and bone produced by plutonium isotopes taken into the body through inhalation or ingestion. The most comprehensive analysis of risks associated with this kind of radiation dose is presented in the report by the National Research Council, Committee on the Biological Effects of Ionizing Radiation (BEIR), entitled "Health Risks of Radon and Other Internally Deposited Alpha-Emitters" (the BEIR IV Report) (NRC, 1988). Although the BEIR committee has published a more recent report than their 1988 BEIR IV report (NRC, 1990), it is not appropriate to use the estimates contained in it for this assessment. The reason is that the 1990 report (BEIR V) does not contain risk estimates for alpha emitters like Plutonium-239 (^{239}Pu). The BEIR IV report is the most recent BEIR committee report containing detailed risk information on the type of radionuclides found at the BOMARC Missile Site. The BEIR IV risk factor cited for lung cancer from internally deposited transuranic radionuclides is 700 lung cancer deaths per million person-rad. For liver the risk estimate is 300 cancer deaths per million person-rad. For bone the range of risk estimates is given as 80 to 1100 cancer deaths per million person-rad. In order to use these risk estimates, the doses obtained using the factors in Table 1-1 in units of mrem must be converted to units of rads. For external doses from gamma rays no conversion is required. For internal doses from alpha emissions the number of rads can be calculated by dividing the number of rems by 20.

1.3 Uncertainties and Sensitivities in Dose and Risk Assessments

Model Uncertainties. The dose and risk estimates in the EIS are presented as discrete values. Each of these calculated values is an expression of impact on an individual or on a population as a whole. These values are intended to be upper-bounds estimates of risk. However, the models used to calculate risk are generalizations and simplifications of the processes which result in exposure and risk. The models that are used are more sensitive to some parameters than to others. In addition, the ability to model the processes is also limited by the availability of data characterizing each site and the understanding of the processes. As a result, the estimates of dose and risk have a considerable degree of uncertainty associated with them.

The sequence of analyses performed to generate the radiological impact estimates includes (1) estimation of releases, (2) estimation of environmental transport and uptake of radionuclides, (3) calculation of radiation doses to exposed individuals, and (4) estimation of health effects. There are uncertainties associated with each of these steps. For instance, the dose calculation models involve the use of simplified representations of complex processes. It is not feasible to obtain sufficient data to fully or accurately characterize transport and exposure processes. Similarly, it is not possible to predict future conditions with certainty. Hence, there will be uncertainties in the representation of the environmental processes as well as in the data required to use the models (due to measurement errors, sampling errors, or natural variability). Finally, there are uncertainties in the calculations themselves (e.g., roundoff errors by the computers).

In principle, one can estimate the uncertainty associated with each source and predict the remaining uncertainty in the results of each set of calculations. Thus, one can propagate the uncertainties from one set of calculations to the next and estimate the uncertainty in the final results. However, conducting such a full-scale quantitative uncertainty analysis is neither practical nor a standard practice for most assessments. Instead, the analysis is designed to ensure - through judicious selection of release scenarios, models, and parameter values - that the results are bounding. That is, the goal is to produce the maximum potential adverse impacts. This is accomplished by using assumptions in the calculations at each step that tend to maximize the potential adverse impacts (i.e., "conservative" assumptions). The models and parameters used in the calculations are selected in such a way that most intermediate results and, consequently, the final estimates of impacts are greater than what would actually be expected. As a result, even though the range of uncertainty in a calculated dose might be large, the dose is likely to be at the high end of the range of possible values. Therefore, the chance of the quantity being greater than the calculated value is low. Thus, a goal of the methodology for the baseline hazard assessment was to produce results that are reasonably conservative.

Finally, the uncertainties in risk associated with internally deposited alpha emitters like ^{239}Pu are often greater than for other types of radionuclides (EPA, 1989). One of the reasons is that there are limited human epidemiological data on the risks from alpha emitters. These data are largely confined to: (1) lung cancer induced by radon decay products, (2) bone cancer induced by radium; and (3) liver cancer induced by injected thorotrast (thorium). The epidemiological data for other types of radionuclides (e.g., gamma-emitting) are much more extensive.

Model Sensitivity. Any computational model will return different final results if input parameters are varied. The degree to which a change in a model parameter value impacts the model results is referred to as the sensitivity of the model to that parameter. If very little change occurs in the model output, the model is said to be insensitive to variations in that parameter. A formal sensitivity analysis involves a quantitative determination of the influence of several parameters on a specified model output. A sensitivity analysis can be very useful in limiting the scope of an uncertainty analysis by identifying those parameters that the model is sensitive to, and thus worthwhile investigating the uncertainties associated with. A formal sensitivity analysis can be very complex, especially on models that are coupled such as in the codes that are used in the EIS radiological assessments. For instance, a variation in a parameter value may greatly affect the output of a single model (e.g., unsaturated zone transport), but may not significantly impact the final output of the code (e.g., radiological dose). Also, there are correlations between parameters that complicate the understanding of the sensitivity of the model to a parameter.

For this EIS, a simplified sensitivity analysis was conducted, using the capabilities of the RESRAD code used for calculation of intruder doses (see Sections 2 and 3). In RESRAD, a single parameter value can be varied plus and minus a preset range over its nominal value. The code then calculates final output values (i.e., radiological doses) using the nominal value and the extremes of the range specified for the nominal value. This gives an indication of the sensitivity of the code to a single parameter. Parameters in three categories were examined for their influence on the output of RESRAD. The categories are: (1) physical site characteristics, (2) radionuclide-specific parameters, and (3) exposure pathway-specific parameters. The results of this type of sensitivity analysis are discussed in Section 3.

2.0 RADIOLOGICAL RELEASES TO THE ENVIRONMENT

To assess potential radiological impacts to workers and the general public, estimates must first be made of the amounts of radioactivity released from the BOMARC Missile Site to the environment for each alternative. This section describes the assumptions, models, and data used for these estimates. Airborne and waterborne releases are the mechanisms by which radionuclides could be released from the BOMARC Missile Site to the uncontrolled environment. However, airborne releases present the only significant mechanism for exposing either on-site workers or off-site individuals. Methods for assessing potential radiation doses due to these releases are presented in Section 3.0.

In order to assess the radiological impacts from the non-uniform contaminated soil at the BOMARC site, the RESRAD guidance regarding in homogeneous contamination was reviewed. For the assessment, the area of the site was divided into four sub-areas based on measured soil contamination levels (see Figure 2-1). These areas are intended only for the purposes of the radiological assessment, and not for other purposes (e.g., areas of required remediation). The data supporting the BOMARC Remedial Investigation/Feasibility Study (RI/FS) (SAIC, 1990) were used to determine characteristics such as maximum concentrations of ^{239}Pu in soil, depth of contamination, and other physical characteristics. Essentially all locations on the BOMARC site that had elevated soil concentrations of ^{239}Pu (based on soil sampling data) as well as all locations that had measurable Americium-241 (^{241}Am) HPG readings are contained within one of the four sub-areas ("elevated" means greater than twice the background level of ^{239}Pu for soil samples). The only exceptions are three sediment samples taken from Elisha Branch south of the developed portion of the BOMARC missile site. The highest of these samples contained 1.8 picocuries per gram (pCi/g) ^{239}Pu, and they averaged 1.08 pCi/g, approximately ten times the background level (0.1 pCi/g). These samples were not included in the analyses because there were only three isolated, elevated sample locations, the levels were not extremely high, there was not a general elevation of contamination levels in the area, and finally, the sample locations are beyond the developed area of the BOMARC missile site. The total area of the four sub-areas is estimated to be 76,500 m^2. Principal characteristics of the four sub-areas are given in Table 2-1.

Table 2-1
Sub-Areas of Contamination on the BOMARC Missile Site Used For the Radiological Assessment

Sub-Area	Area (m^2)	Maximum ^{239}Pu Concentration (pCi/g)	Maximum Depth of Contamination (m)	Average ^{239}Pu Concentration to Maximum Depth (pCi/g)
1	16,000	240	3.05	22.6
2	18,800	180	1.83	20.6
3	10,800	3.9	1.22	3.9
4	30,900	3.3	0.15	3.3

Note: The maximum concentrations listed are for the 0 - 6 inch soil sampling depth.

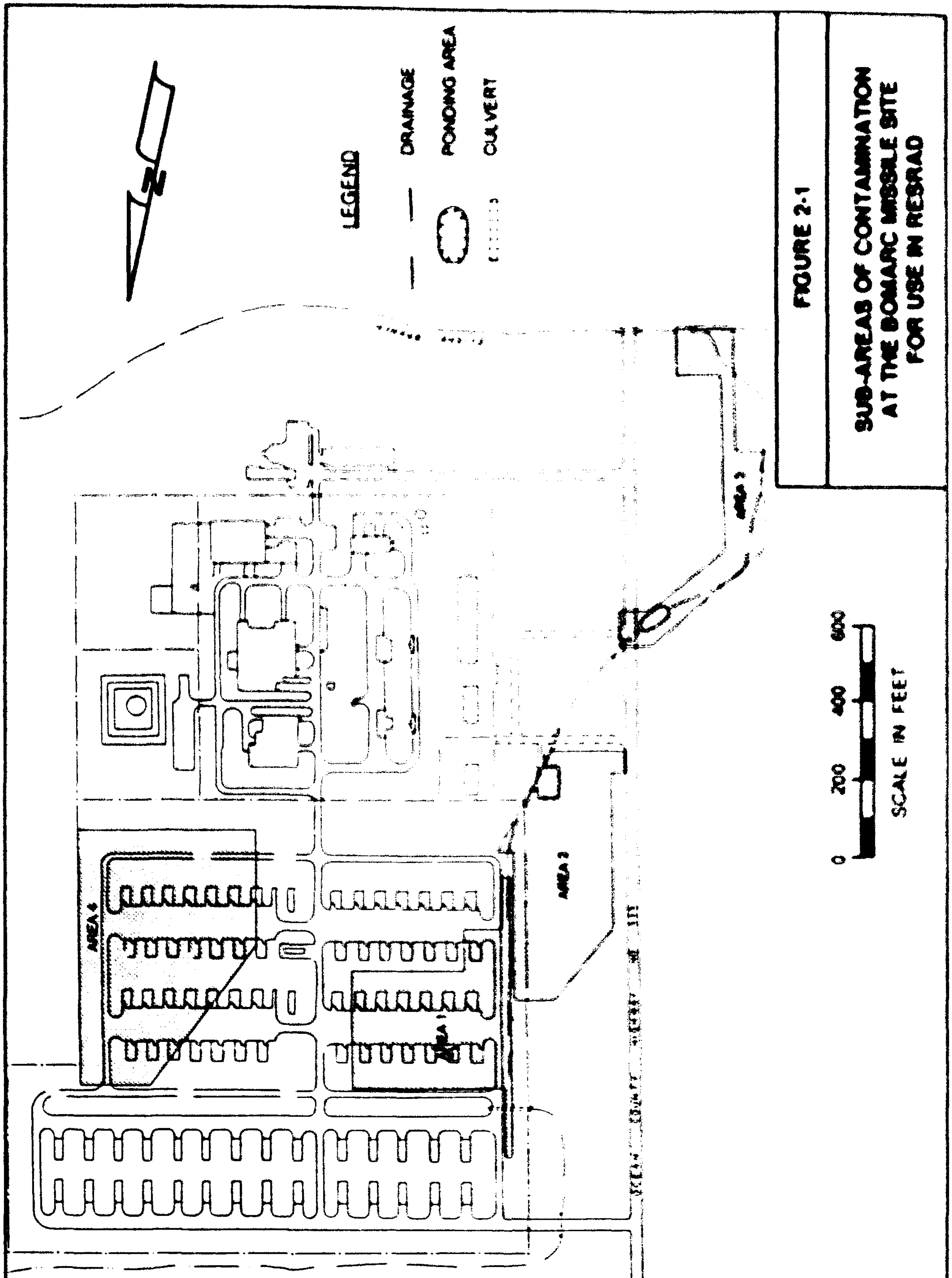

FIGURE 2-1

SUB-AREAS OF CONTAMINATION AT THE BOMARC MISSILE SITE FOR USE IN RESRAD

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The maximum concentration level in each sub-area was first estimated by combining the maximum concentration values at each depth from various soil sample locations within each sub area. The average soil contamination level within each area was then assumed to be one third of the maximum composite values (Gilbert *et al.*, 1989). The depth profile samples were not used to determine contamination levels because there was not enough information consistently available to make the samples useful. In particular, the weights of each particle size fraction were not always available, and thus the activity concentrations could not be calculated. Although high ^{239}Pu concentrations were obtained from some of these samples (e.g., 150,000 pCi/g), the high values are likely due to discrete particles rather than uniform contamination levels of an entire sample. This is supported by much lower concentrations in samples taken adjacent to the locations of high levels.

Preliminary results of the RESRAD code indicated that using the average soil concentration in the top soil sampling layer (generally 6 inches) produced higher doses than using a depth weighted average concentration to the maximum depth. Therefore, the 0-6 inch depth concentrations were used in the final assessments.

2.1 Airborne Releases

Airborne particulates contaminated with plutonium and americium are the dominant hazard associated with the cleanup of the BOMARC Missile Site. Resuspension of contaminated soil during undisturbed periods and fugitive dusts during remediation activities are the primary mechanisms by which airborne transport occur. Although no specific resuspension studies have been conducted at the BOMARC Missile Site, a conservative estimate of resuspension can be made (see Section 2.1.2). To address the radiological impacts of the alternatives, the analysis requires consideration of the following alternatives.

1. <u>Off-site Disposal</u>. This alternative consists of excavation of soils, demolition of structures, and transport of these materials for disposal at a permitted off-site facility. These actions are characterized by the potential for fugitive dusts during remediation, however, it is assumed that all necessary measures would be taken to prevent the release of significant amounts of contaminated dust during remediation (see Section 2.1 of EIS). This alternative would result in a reduction in surface contamination levels. Therefore, the radioactivity available for atmospheric release from soils over the long term is assumed to be from soils remediated to the planned cleanup level of 8 pCi/g for areas that now exceed that level and at the existing baseline levels elsewhere on the site. The average surface soil concentration of ^{239}Pu on the site after remediation is calculated to be 4.3 pCi/g.

2. <u>Unrestricted Access</u>. If this scenario were to occur, no institutional controls or remedial measures would be implemented. The site is characterized by long-term conditions during which resuspended material may potentially be dispersed off the site to expose the general public. The lack of institutional controls allows for the possibility of intruder scenarios, whereby members of the public could gain access and disturb the site. Radioactivity available for atmospheric release is assumed to include the existing surface soil contamination and additional contamination resulting from disturbance of the buried launcher during

construction of a basement by an intruder. The average site surface soil concentration of ^{239}Pu for assessment of long-term impacts of this alternative was calculated to be approximately 65 pCi/g. No occupational activities are planned for this alternative so no evaluation of worker doses has been made.

3. National Environmental Policy Act (NEPA) No Action. This alternative consists of a continuation of current operational procedures designed to protect human health and the environment at the site. Contaminated areas would continue to be fenced and posted to preclude public access. The site would still be inspected on a regular basis to verify that conditions do not deteriorate to the point that public exposure is a concern. The concrete apron and building structures would be maintained and repaired as necessary, and radiological surveys would continue to be conducted annually to ensure that contaminants are not migrating from the site. However, there would be the potential for limited airborne release of plutonium and americium via resuspension. Under this alternative the missing missile launcher would not be located and removed. The radioactivity available for atmospheric release over the long term is assumed to include only the existing average surface soil contamination (32 pCi/g).

4. Limited Action. The Limited Action Alternative consists of several actions resulting in institutional control of the site. Contaminated areas would be fenced and posted to preclude public access. The site would be inspected on a regular basis to verify that conditions do not deteriorate to the point that public exposure is a concern. The concrete apron and building structures would be maintained and repaired as necessary, and radiological surveys would be conducted annually to ensure that contaminants are not migrating from the site. Like the No Action Alternative, there would be limited airborne release of plutonium and americium via resuspension. Under this alternative the missing missile launcher would be located and removed. Removal of the launcher precludes the possibility of additional surface contamination resulting from inadvertent missile launcher discovery. Therefore, the radioactivity available for atmospheric release over the long term is assumed to include only the existing average surface soil contamination (32 pCi/g).

5. On-site Treatment. This alternative includes both on-site and in situ treatment alternatives whereby the plutonium and americium would be either immobilized or concentrated and removed from wastes for subsequent shipment off-site. Like the Proposed Alternative, this alternative involves on-site procedures that pose the potential for release of radioactively-contaminated material. However, it is assumed that measures would be taken (see Section 2.5 of the EIS) to prevent the release of significant amounts of pollutants. Also like the Proposed Alternative, this alternative would result in a reduction in the surface contamination levels to an average ^{239}Pu concentration of approximately 4.3 pCi/g after remediation.

2.1.1 BOMARC Missile Site Surface Contamination

Before estimating resuspension and off-site dispersion of ^{239}Pu and ^{241}Am from contaminated surface soils, average levels of contamination were needed for each EIS Alternative. In order

to be consistent with the bases for other calculations (e.g., intruder doses - Section 3.2), the mass concentrations of ^{239}Pu obtained from the soil samples taken as part of the RI/FS process (TETC, 1992) were used to estimate average surface soil concentrations of ^{239}Pu. The following assumptions were made in order to estimate surface areas and areal surface contamination levels for each alternative. Areal concentrations (in units of $\mu Ci/m^2$) were used only for resuspension leading to off-site dispersion estimates. A summary of the values calculated is given in Table 2-2.

Table 2-2
Surface Soil Contamination Levels for Estimating Off-Site Airborne Releases Over the Long Term

Alternative	Area (m^2)	^{239}Pu Concentration[a] ($\mu Ci/m^2$)	Description
Unrestricted Access	1,963	102	Intruder basement construction
	74,537	2.4	Existing baseline levels in remaining areas
	76,500	5	Average over total area[b]
NEPA No Action and Limited Action	76,500	2.6	Existing baseline levels
Proposed and On-site Treatment	34,800	0.64	Planned cleanup level
	10,800	0.10	Existing baseline level in remaining areas
	30,900	0.09	Existing baseline level in remaining areas
	76,500	0.34	Average over total area[b]

a. Calculated for a depth of 5 cm.

b. This average value is a sum of the values for each area, weighted by the fraction of the total area each area contains.

For the **Unrestricted Access Alternative**, additional contamination from a hypothetical intruder excavating a basement with a volume of 906 m^3 on the site is assumed to be spread over a radius of 25 m and a depth of 0.46 m, resulting in a contaminated surface area of 1,963 m^2. The total concentration of ^{239}Pu in this area from contamination associated with the launcher plus existing soil contamination would be 1,270 pCi/g to a depth of 0.46 m (the existing soil contamination levels in the basement excavation soil add less than 1% to this total activity). It is assumed that only the top 0.05 m of the 25-m radius area would be available for resuspension and off-site dispersion. Assuming a soil density of 1.6 g/cm^3, the areal concentration in this top 5 cm layer of the soil would be approximately 102 $\mu Ci/m^2$. The remainder of the contaminated areas for this alternative would have an average areal concentration of approximately 2.4 $\mu Ci/m^2$. An average areal site concentration of approximately 5 $\mu Ci/m^2$ was calculated by weighting (by area) and summing the contamination levels in the 25-m radius area and the remainder of the site. The scenario used for this evaluation is described more fully in Section 3.2.

For the **NEPA No-Action and Limited Action Alternatives**, the calculated existing baseline concentration of 32 pCi/g was used to calculate an areal concentration of 2.6 $\mu Ci/m^2$ for a depth of 5 cm. For the **Off-site Disposal and the On-Site Treatment Alternatives**, the average contamination level was calculated by combining the remediated concentrations of sub-areas 1

and 2 (8 pCi/g) and the existing levels in sub-areas 3 and 4 (1.3 and 1.1 pCi/g average concentrations, respectively). The average site ^{239}Pu concentration was thus calculated to be 4.3 pCi/g with a corresponding areal concentration of 0.34 μCi/m^2 to a depth of 5 cm.

2.1.2 Resuspension of Contaminated Particles

Resuspension from soils and subsequent inhalation of the resuspended material has long been considered the chief source of exposure to transuranium elements deposited in soils. The best method for determining quantities and rates of resuspension of contaminated surface soils is to directly measure air concentrations in the vicinity of contaminated soils. However, in order to obtain average concentrations, measurements must be done over a long period of time and under a variety of conditions. Therefore, direct measurements are not always practicable. Consequently, estimates of surface soil resuspension are most commonly obtained by modeling techniques. Although many resuspension modeling techniques are available, the following three basic techniques are most commonly used: (1) the resuspension factor model, (2) the resuspension rate approach, and (3) the mass loading approach (Healy, 1980). Each method has its strengths and its weaknesses, particularly in view of the state of the technology at this time. The resuspension rate and mass-loading techniques are used directly in this assessment. The resuspension rate model is used in the off-site dispersion and dose calculations because it yields fractional resuspension per unit time, and because the area subjected to resuspension can be incorporated into calculations. The mass-loading approach is used in the on-site dose calculations because it relates surface soil concentration to the concentration in air in the immediate vicinity. The following discussion describes all three most common approaches, how they are related, and specific applications to the BOMARC site.

The assessments for the BOMARC Missile Site used two computer models. GENII was used for off-site population doses and RESRAD was used for on-site intruder doses. GENII does not treat resuspension directly but accepts a radionuclide release rate as input. RESRAD uses a mass loading approach. In order to insure consistency between these two models for the BOMARC Missile Site, the release rate for GENII input was derived from the RESRAD default mass loading value using the equations presented here.

In the **resuspension factor model**, the airborne dust concentration is given as a function of an empirically determined resuspension factor, the effective depth of the layer of soil from which resuspension occurs, and the bulk density of soil. The equation relating these parameters is

$$C_{dust} = R_f \times d_r \times \rho_b$$

where

C_{dust}	=	airborne dust concentration (g/m^3)
R_f	=	resuspension factor (m^{-1})
d_r	=	depth of soil (m)
ρ_b	=	density of surface soil (g/m^3).

In the **resuspension rate model**, the airborne dust concentration is given as a function of an empirically determined fractional resuspension rate, the areal density of soil, and the average deposition velocity of resuspended soil particles. The equation is

$$C_{dust} = (R_r \times \sigma_s) \div v_d$$

where

C_{dust}	=	airborne dust concentration (g/m^3)
R_r	=	fractional resuspension rate (s^{-1})
v_d	=	deposition velocity (m/s)
σ_s	=	areal density of soil (g/m^2)

and

$$\sigma_s = d_s \times \rho_b.$$

The third model is a mass loading model in which the value of airborne dust concentration is specified using empirical data or measured values of airborne dust under similar conditions.

$$C_{dust} = M$$

where

C_{dust}	=	airborne dust concentration (g/m^3)
M	=	mass loading factor (g/m^3)

The three models discussed above are not independent. They can be related by the following equalities:

$$R_f = M \div \sigma_s = M \div (d_s \times \rho_b) \quad \text{(ref: Gilbert } et\ al.\ \text{1989)}$$

and

$$R_r = R_f \times v_d. \quad \text{(ref: Napier } et\ al.\text{, 1988)}$$

Combining these two equations gives the following expression for the fractional resuspension rate in terms of the mass loading factor:

$$R_r = (M \times v_d) \div (d_s \times \rho_b)$$

In the BOMARC EIS radiological assessments, two separate computer codes were used. RESRAD was used for estimating doses to individuals, including intruders, located on the BOMARC site (see Section 3.2.2). GENII was used for estimating doses to the surrounding population located outside the site boundary out to a distance of 50 miles. RESRAD is specifically designed to estimate on-site doses for facilities with radioactively contaminated soils. In addition, it is intended to help set clean up criteria for those facilities. Therefore, it was considered to be the best available code for these BOMARC assessments. However, RESRAD does not allow calculation of dose to the surrounding population. GENII was chosen to supplement RESRAD for the BOMARC assessments. GENII is a flexible, general purpose radiological assessment code capable of estimating doses to the surrounding population from ground level releases of airborne radioactivity (see Section 2.1.3).

A mass loading model is used in RESRAD to estimate air concentrations of resuspended particulates. GENII does not automatically estimate off-site releases from resuspension but must be supplied with an annual release rate. The equation above expressing the fractional resuspension rate in terms of the mass loading factor was used to estimate a release rate for the GENII calculation that is consistent with the RESRAD mass loading model.

$$R_s = (M \times v_d) \div (d_s \times \rho_s)$$

where

d_s	=	5.1 cm = 0.051 m
ρ_s	=	1.6 g/cm³ = 1.6×10^6 g/m³
M	=	200 μg/m³ = 2.0×10^{-4} g/m³
v_d	=	2 cm/s = 0.02 m/s

gives

R_s	=	$4.9 \times 10^{-11}\ s^{-1} = 1.5 \times 10^{-3}\ y^{-1}$

The value for d_s is a conservative value assumed for the BOMARC EIS calculations. The values for ρ_s and M are those used in the RESRAD calculations. The value of 200 μg/m³ for M is not a site-specific value. It is the default value chosen by the authors of RESRAD (Gilbert *et al.* 1989), and is two times the generic value suggested by the NCRP (NCRP, 1985). The value is therefore a conservative one, however, it is applicable to a broad range of circumstances, including the on-site residence scenario evaluated for the BOMARC Missile Site. The deposition velocity, v_d, is based on 10 μm resuspended soil particles and a friction velocity of 50 cm/s appropriate to the BOMARC site (Whicker and Shultz, 1982).

The fractional resuspension rate gives a total annual release according to the following equation:

$$Q = R_s \times A \times C_{surf}$$

where

Q	=	total annual release rate (μCi/y)
R_s	=	fractional resuspension rate (y^{-1})
A	=	surface area (m²)
C_{surf}	=	surface concentration (μCi/m²)

For the BOMARC site, the fractional resuspension rate of $1.5 \times 10^{-3}\ y^{-1}$ was used in conjunction with areas and surface concentration levels to estimate total annual atmospheric release rates in units of μCi/yr. This is the input required by GENII for calculating atmospheric dispersion and subsequent radiation dose from a ground level release. Table 2-3 shows the average ^{239}Pu concentrations calculated in Section 2.1.1, the areas considered, and the calculated annual releases of radionuclides for each EIS Alternative.

Table 2-3
Annual ^{239}Pu Release Rates from the BOMARC Site for Estimating Off-Site Population Doses

EIS Alternative	Average ^{239}Pu Concentration (μCi/m²)	Area (m²)	Resuspension Rate (y^{-1})	Annual ^{239}Pu Release (μCi/y)
1. Off-site Disposal	0.34	76,500	0.0015	40
2. Unrestricted Access	5	76,500	0.0015	575
3. NEPA No-Action	2.6	76,500	0.0015	300
4. Limited Action	2.6	76,500	0.0015	300

Table 2-3
Annual ^{239}Pu Release Rates from the BOMARC Site for Estimating Off-Site Population Doses
(Continued)

EIS Alternative	Average ^{239}Pu Concentration (μCi/m^2)	Area (m^2)	Resuspension Rate (y^{-1})	Annual ^{239}Pu Release (μCi/y)
5 On-Site Treatment	0.34	76,500	0.0015	40

NOTES: Average ^{239}Pu concentrations and Areas taken from Table 2-2
Resuspension rate calculated in Section 2.1.2
Releases of ^{241}Am can be calculated by dividing the ^{239}Pu releases by 5.9

2.1.3 Off-site Atmospheric Dispersion

Atmospheric dispersion of contaminated material to distances beyond the BOMARC Missile Site was evaluated using the appropriate modules of the GENII computer code (Napier *et al.*, 1988). GENII is a code developed by Battelle Pacific Northwest Laboratory (PNL) to assess the radiological consequences of releases to the environment. It allows several options for atmospheric dispersion calculations. Further, it is coupled directly to the dosimetry calculations necessary for assessing the potential impacts to the general public.

This assessment uses the straight-line Gaussian plume option of GENII for long-term, undisturbed conditions. The straight-line Gaussian plume model is the basis for a set of dispersion models that are widely accepted for routine dose assessment applications.

For this analysis, annual average air concentrations are estimated on a 16-sector grid out to a distance of 50 miles (80 km) as a basis for estimating potential impacts to the general public surrounding the site. The population surrounding the BOMARC Missile Site used to calculate the population dose is the estimated 1995 population. The assumed population is shown in Table 2-4.

Other requirements for this calculation include the frequency of occurrence for winds, wind speeds, and stability class in each sector. These data are available for McGuire AFB and are summarized in STAR format, which presents the joint frequency of wind speed and stability (Table 2-5).

2.2 Waterborne Releases

In addition to airborne releases from the BOMARC Missile Site, waterborne releases were considered.

Table 2-4
Population Forecast for BOMARC Missile Site Area - 1995[a]

Direction	Outer Radius (miles) 1	2	3	4	5	10	20	30	40	50
S	0	0	0	0	32	10,071	34,931	51,605	61,753	42,067
SSW	0	0	0	0	119	8,915	32,502	50,806	58,420	69,726
SW	0	0	0	0	0	8,453	32,502	76,204	185,880	85,913
WSW	0	0	0	0	0	8,298	32,502	59,175	314,380	328,145
W	0	0	78	198	240	8,453	32,502	158,134	868,405	630,755
WNW	0	52	208	297	375	10,143	42,144	94,159	148,676	204,130
NW	0	141	214	297	375	19,400	89,976	145,215	81,479	96,614
NNW	0	134	207	280	356	17,108	104,397	145,806	98,141	83,055
N	0	0	0	203	177	14,242	94,513	238,987	282,427	479,833
NNE	0	0	0	242	236	10,967	74,492	154,901	297,060	1,656,262
NE	0	0	0	0	310	10,148	71,680	121,506	41,612	595,909
ENE	0	0	0	0	310	10,148	59,794	52,431	0	0
E	0	0	0	0	90	10,148	39,325	5,074	0	0
ESE	0	0	0	314	909	10,148	39,748	10,148	0	0
SE	0	0	52	0	1,258	10,148	39,748	33,828	0	0
SSE	0	0	122	716	1,031	10,148	39,748	57,931	22,834	0

[a] Entries are in number of persons per sector. Total population: 9.24 million.

Table 2-5
Meteorological Data* for the GENII Population Dose Calculations for the BOMARC Missile Site

	Wind from:	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WSW	NW	NNW
Average Windspeed (m/sec)																	
	0.8	0.08	0.03	0.03	0.04	0.04	0.01	0.02	0.03	0.09	0.06	0.07	0.06	0.11	0.06	0.07	0.06
	2.57	0.02	0.02	0.01	0.01	0.02	0.00	0.01	0.02	0.03	0.02	0.05	0.02	0.06	0.04	0.04	0.03
Class A	4.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	9.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	12.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.8	0.27	0.20	0.13	0.11	0.13	0.11	0.09	0.11	0.24	0.19	0.24	0.25	0.34	0.22	0.19	0.19
	2.57	0.21	0.17	0.14	0.08	0.13	0.09	0.08	0.09	0.15	0.16	0.28	0.25	0.40	0.24	0.19	0.17
Class B	4.37	0.10	0.05	0.04	0.03	0.04	0.03	0.03	0.01	0.05	0.07	013	0.11	0.15	0.09	0.10	0.09
	6.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	9.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	12.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.8	0.23	0.12	0.10	0.10	0.13	0.10	0.09	0.16	0.28	0.25	0.18	0.15	0.21	0.12	0.11	0.14
	2.57	0.30	0.20	0.11	0.08	0.13	0.14	0.12	0.15	0.25	0.23	0.28	0.27	0.38	0.28	0.24	0.21
Class C	4.37	0.42	0.17	0.14	0.12	0.15	0.11	0.09	0.17	0.26	0.42	0.54	[illegible]	0.64	0.61	0.45	0.40
	6.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	9.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	12.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

(Continued)

* Numbers in the main body of the text are fraction of time for persistence of conditions (Stability Classes A-G and windspeed category) for compass directions. The wind blows from the directions indicated.

Table 2-5

Meteorological Data* for the GENII Population Dose Calculations for the BOMARC Missile Site (Continued)

	Wind from:	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WSW	NW	NNW
	0.9	0.53	0.49	0.57	0.51	0.92	0.57	0.44	0.58	1.01	0.61	0.43	0.33	0.47	0.22	0.24	0.31
	2.57	0.68	0.51	0.61	0.61	1.07	0.56	0.44	0.54	1.09	0.82	0.61	0.50	0.68	0.39	0.43	0.38
	4.37	1.05	0.80	0.67	0.59	0.95	0.48	0.29	0.45	1.16	0.80	0.77	0.78	1.32	1.24	0.94	0.87
Class D	5.94	0.77	0.47	0.35	0.25	0.28	0.09	0.06	0.07	0.20	0.23	0.42	0.72	2.06	1.90	1.40	1.00
	9.64	0.12	0.05	0.04	0.04	0.03	0.00	0.01	0.01	0.02	0.01	0.05	0.07	0.45	0.45	0.31	0.14
	12.86	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.05	0.16	0.10	0.12	0.03
	0.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.57	0.23	0.16	0.14	0.08	0.14	0.11	0.13	0.34	0.94	0.60	0.32	0.27	0.31	0.30	0.22	0.23
	4.37	0.31	0.05	0.01	0.01	0.01	0.01	0.01	0.04	0.16	0.11	0.16	0.22	0.99	0.90	0.55	0.49
Class E	6.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	9.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	12.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.8	0.57	0.26	0.25	0.26	0.34	0.18	0.30	0.64	1.55	1.13	0.76	0.48	0.78	0.49	0.40	0.55
	2.57	0.51	0.09	0.04	0.03	0.04	0.05	0.07	0.20	0.80	0.60	0.61	0.49	1.07	0.75	0.57	0.67
Class F	4.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	9.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	12.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.8	0.85	0.25	0.19	0.14	0.29	0.25	0.27	0.62	2.35	1.63	1.04	0.85	1.38	0.86	0.86	0.86
	2.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Class G	4.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	9.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	12.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

* Numbers in the main body of the text are fraction of time for persistence of conditions (Stability Classes A-G and windspeed category) for compass directions. The wind blows from the directions indicated.

2.2.1 Groundwater Releases

Groundwater releases are evaluated in the construction/resident scenario (Section 3.2). This analysis provides a conservative estimate of groundwater release, as the intruder obtains water from a well located at the site. Results indicate that the groundwater pathway is insignificant relative to the airborne pathway.

2.2.2 Surface Water Releases

There are no permanent surface waters on the dry, upland soils of the BOMARC Missile Site The principal surface water features associated with the site are the natural streams that drain the nearby low wetlands of the Pinelands. A majority of the surface runoff from both the missile launch area and support facilities, drains to the west, south, and east and eventually reaches the Elisha Branch. From Elisha Branch, surface water flows into larger tributaries leading to the Ridgeway Branch, the Tom's River, and ultimately reaches the Atlantic Ocean via Barnegat Bay.

The surface water pathway was not considered in the dose analyses for the following reasons. First, man-made control systems limit surface erosion and favor infiltration into the ground. The asphalt and concrete cover placed in the vicinity of Shelter 204 and in the drainage result in rapid runoff; however, the area covered is protected from surface erosion and transport of contaminated sediments. Some restriction to flow may occur on the upstream side of road culverts, which could result in ponding and augmented infiltration into the ground. Additional groundwater recharge over the long term is expected in the depression located at the downstream side of the culvert under Ocean County Highway No. 539.

Second, surface waters in the near vicinity of the BOMARC Missile Site, i.e., the Elisha Branch and immediate downstream water courses, are not known to be presently in use as a water supply source. Third, the high recharge potential of the native sandy soils minimizes surface runoff. Finally, in light of the above discussion, the amount of contamination that could potentially reach surface waters used by humans is insignificant compared with that transported by air or groundwater.

3.0 METHODS FOR ASSESSING POTENTIAL RADIOLOGICAL IMPACTS

Because of the releases discussed previously (Section 2.0), members of the public may be exposed to radioactive material from the BOMARC Missile Site. These potential exposures (doses) may result in subsequent health effects in the exposed population as discussed in Section 1.2. This section explains how radiation doses for the general public are calculated.

The methods used for assessing the radiological impacts on members of the general public are described in this section. Both long-term, undisturbed conditions and active remediation conditions are evaluated. Two types of calculations are done for this assessment: (1) potential dose to the population within 50 miles (80 km) of the site (Section 3.1) and (2) doses to inadvertent intruders (Section 3.2).

3.1 <u>Potential Population Dose</u>

Potential dose to the population was estimated using the GENII dose calculation program (Napier *et al.*, 1988). This program was used to model chronic releases to the atmosphere as described in Section 2.1.2. The basic input to GENII is a list of types and amounts of radionuclides released to the environment; Table 2-3 contains these calculated releases for each Alternative. Based on historical meteorological records for McGuire AFB, GENII then calculates the expected annual average air concentration in zones defined by radial intervals of 16 sectors out to a distance of 50 miles from the point of emission. Air concentrations are estimated using the straight-line Gaussian plume model of dispersion. The code takes into account the height of the emission point (ground-level releases were assumed for this assessment), radioactive decay of specific radionuclides, and other appropriate factors.

GENII then calculates the quantities of specific radionuclides that would be deposited in each of the 16 sectors and that could result in human exposure by various pathways. GENII then calculates the radiation doses to the entire population in all 16 sectors (population estimates for each sector are part of the input to GENII; see Section 2.1.3). The code is used only to calculate the population dose for this assessment, but it can also identify the dose for maximally exposed off-site individual. Potential pathways of exposure calculated by GENII include external radiation from contaminated air and ground surface as well as internal radiation dose from inhalation and ingestion of contaminated foods. Both EDE and organ dose commitments are reported in the public health sections of the EIS. To convert doses, which are expressed in terms of person-rem, to health effects, the doses were multiplied by risk factors recommended by the BEIR IV committee (see Section 1.2).

Input parameters used and output table from GENII for the population dose scenario are provided in Annex 1 of this appendix.

3.2 Potential Doses to Inadvertent Intruders

The Unrestricted Access Alternative includes an assessment that evaluates the potential for radiation dose to individual members of the general public who may inadvertently expose themselves to soil or other contamination at the BOMARC Missile Site. All other alternatives assume either remediation of contaminated soil or long-term institutional control of the site, and therefore preclude significant exposure of intruders. The Inadvertent Intruder assessment is a hypothetical worst-case scenario, and includes a family farm assumption. To estimate the upper bound (worst-case) for doses to an intruder, it is assumed for the Unrestricted Access Alternative that long-term institutional control of the site would not exist and members of the public would have unrestricted access to the site at some time in the indefinite future. It was assumed that the intruder entered the sub-area resulting in the highest dose consequences (Sub-area 1).

In order to assess the intruder scenario, one of the scenarios used by the NRC for waste disposal assessments (Kennedy and Peloquin, 1988) was adapted. The construction/resident scenario is considered to be a worst-case scenario for this assessment. The construction/resident scenario consists of two parts. First, it is assumed that the intruder contacts with the buried missile launcher, which is assumed to be contaminated for this worst-case scenario, while performing excavation work associated with the construction of a basement for a house (Section 3.2.1).

Second, following house construction, the intruder takes up residence on the site and grows food crops in soil contaminated with both existing surface soil radioactivity and some additional radioactivity resulting from disturbing the missile launcher during excavation (Section 3.2.2).

3.2.1 Intruder - Construction

The first part of the construction/resident scenario is discovery of the buried missile launcher during excavation. Potential doses from excavation work are estimated using a scenario adapted from that used by the NRC for waste disposal assessments (Kennedy and Peloquin, 1988). The general outline of the scenario used by the NRC is directly applicable to the BOMARC Missile Site. The NRC assumes that this scenario would occur after the shutdown of operations at a disposal facility. Institutional controls are assumed to break down and an intruder inadvertently constructs a house on the disposal facility. Although the BOMARC Missile Site is not a disposal facility, there are sufficient similarities between the two situations that the NRC scenario is applicable to this site. The NRC dimensions used are close enough to what would occur for the launcher discovery and excavation, therefore the NRC scenario dimensions were not altered. Additionally, the NRC assumptions are consistent with those given in the RESRAD documentation (Gilbert *et al*, 1989).

The NRC scenario assumes that the intruder contacts the disposed wastes while performing excavation work associated with the construction of a basement for a house (Appendix G from NRC, 1981). This construction work is assumed to last for 500 working hours or the equivalent of a 3-month construction period. The dust loading (dust concentration in the air) is assumed to be 0.565 mg per m^3. The NRC scenario represents the basement as a 3-m deep hole with bottom surface area of 20 × 10 m (200 m^2) and a top surface area of 26 × 16 m (416 m^2), giving a 1:1 slope for the side of the excavation. The volume of the excavation is equal to 906 m^3. A schematic of this excavation (Figure 3-1) and its dimensions (Table 3-1) are provided.

Table 3-1
Assumed Launcher Excavation Dimensions for BOMARC Construction Scenario

Physical Dimensions of Excavation:[a]	
Depth of excavation (h):	3 m
Length at bottom (a):	20 m
Width at bottom (b):	10 m
Length at surface (c):	26 m
Width at surface (d):	16 m
Area at bottom:	200 m^2
Area at surface:	416 m^2
Volume of excavation:	906 m^3
Depth of contamination (e):	10 cm

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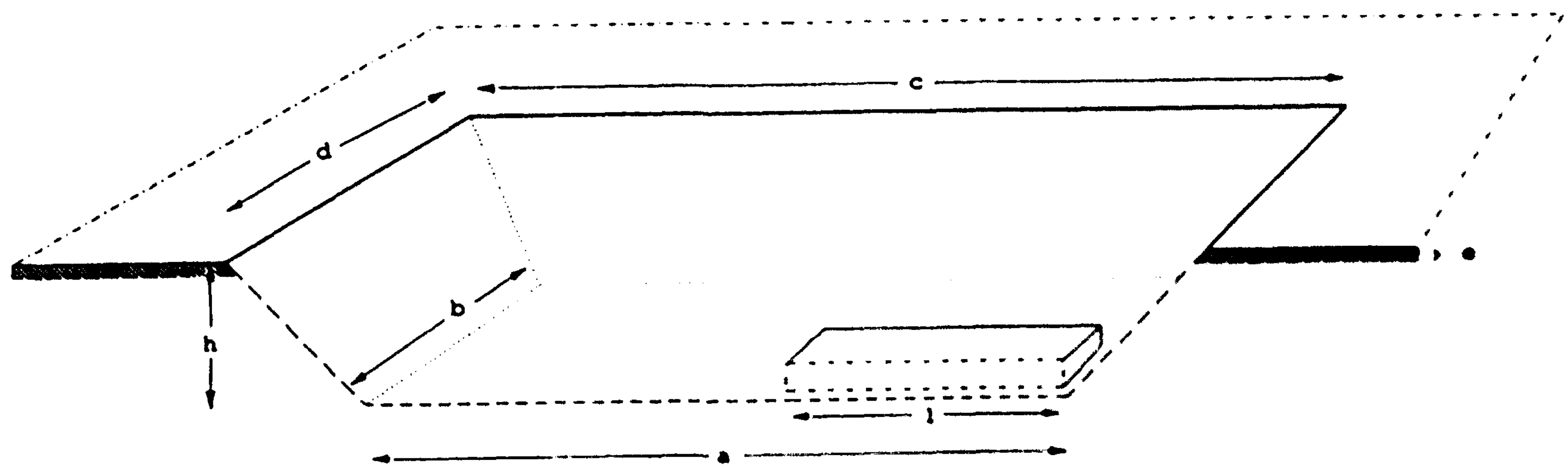

(Refer to Table 4-2 for dimensions)

FIGURE 3-1

SCHEMATIC OF LAUNCHER EXCAVATION FOR BOMARC CONSTRUCTION SCENARIO

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Table 3-1
Assumed Launcher Excavation Dimensions for BOMARC Construction Scenario
(Continued)

Physical Dimensions of Launcher:	
Length (l)	10 m
Width	2 m
Height	2 m

[a]Letters in parentheses refer to labels in Figure 3-1.

For low-level waste disposal site assessments, the NRC assumes that cover material has been placed over the waste during disposal operations below which lies decomposed waste and soil or other backfill. For application to the BOMARC Missile Site it has been assumed that there are two sources of contamination: (1) existing surface soil contamination as characterized by site surveys and (2) contamination associated with the buried launcher. It is further assumed that there is no cover over the contaminated soil.

Using conservative assumptions and the soil sampling data in the RI/FS, the existing surface soil contamination in sub-area 1 (see Section 2) has a calculated maximum concentration of 22.6 pCi/g ^{239}Pu and 3.8 pCi/g ^{241}Am, to a depth of 10 ft. Because of the assumed depth of the launcher discovery scenario (3 m), the 10 ft depth concentration was used rather than the 6 inch concentration. The value of 22.6 pCi/g was calculated by averaging maximum soil sampling results at various depths. In order to calculate an average 10 ft. depth concentration (rather than maximum concentration), one-third of the maximum 22.6 pCi/g value was used (7.5 pCi/g). The total amount of this existing surface soil radioactivity disturbed by excavation of a hole with an area at the surface of 416 m^2 and a volume of 906 m^3 would be 10,940 μCi ^{239}Pu and 1,860 μCi ^{241}Am. This contamination is assumed to be in the form of plutonium and americium oxides as particles with the same size distribution as the surface soil.

The Air Force is not certain that the missing launcher is on the BOMARC site, nor, if it is on the site, how much contamination is associated with it. For the purposes of the radiological assessment for the Unrestricted Access Alternative, it is assumed that the launcher is buried somewhere on the BOMARC site, and that it is discovered by the inadvertent intruder. The best estimate for the maximum residual plutonium on-site is 300 g (BOMARC RI/FS). In order to bound the potential intruder dose for the Unrestricted Access Alternative, it was assumed that 300 g of ^{239}Pu (and associated ^{241}Am) is physically located with the launcher. Most of this activity (18.4 Ci ^{239}Pu and 3.1 Ci ^{241}Am) is assumed to be fixed to the surface of the launcher structure.

The radioactive material associated with the launcher was assumed to be 90 percent fixed surficial contamination and 10 percent removable contamination. Thus, 1.84 Ci of ^{239}Pu is assumed to be lost from the launcher upon discovery. The removable contamination is assumed to be 90 percent large, nondispersable particles and 10 percent particles with the same size

distribution as surface soils. Removal, handling, and sectioning of the launcher is assumed to uniformly contaminate all the soil within 0.5 m of the launcher (100 m^3 of soil). This contaminated soil then contributes to the radiation dose received by the intruder during basement construction.

The radiation dose to an intruder during the excavation and construction phase from each radionuclide, i, is given by

$$D_{total\,i} = D_{grd\,i} + D_{air\,i} + D_{inh\,i}$$

where

$D_{total\,i}$	=	total radiation dose (mrem)

and

$D_{grd\,i}$	=	external radiation dose from contaminated ground surfaces for radionuclide i (mrem),
$D_{air\,i}$	=	external radiation dose from submersion in contaminated air for radionuclide i (mrem),
$D_{inh\,i}$	=	internal radiation dose commitment from inhalation of radionuclide i (mrem).

Because the radionuclides of interest are not primarily photon emitters, external radiation is not expected to pose a significant hazard to an inadvertent intruder on the BOMARC Missile Site. However, two pathways exist with a potential for external exposure and both were evaluated.

External radiation dose from contaminated ground surface is given by

$$D_{grd\,i} = T \times C_i \times DCF_{grd\,i}$$

where

T	=	time spent during construction (yr),
C_i	=	soil concentration of nuclide i (μCi per cm^2),
$DCF_{grd\,i}$	=	dose conversion factor for nuclide i (mrem/year per $\mu Ci/cm^2$).

External radiation dose from immersion in contaminated air is given by

$$D_{air\,i} = T \times X_i \times DCF_{air\,i}$$

where

T	=	time spent during construction (yr),
X_i	=	air concentration of nuclide i (μCi per cm^3),
DCF_i	=	dose conversion factor for nuclide i (mrem/year per $\mu Ci/cm^3$).

The pathway of primary concern at the BOMARC Missile Site is inhalation of air contaminated with dusts containing alpha emitting radionuclides. Internal radiation dose from inhalation is given by

$$D_{inh,i} = T \times X_i \times BR \times DCF_{inh,i}$$

where

$D_{inh,i}$	=	internal radiation dose commitment from inhalation of radionuclide i (mrem)

and

T	=	time spent during construction (yr),
X_i	=	air concentration for nuclide i (μCi per cm^3),
BR	=	breathing rate (cm^3 per year),
$DCF_{inh,i}$	=	dose conversion factor for nuclide i (mrem per μCi).

The air concentration for each radionuclide, X_i, is estimated using the following equation:

$$X_i = (C_i \times DL) \div \rho$$

where

C_i	=	volume concentration of resuspendable contamination in soil for nuclide i (μCi per cm^3),
ρ	=	density of soil (g per cm^3),
DL	=	dust loading of air during construction (g per cm^3).

3.2.2 Intruder - Resident

The second part of the construction/resident scenario consists of an agricultural/resident scenario. This scenario provides upper-bound estimates of potential doses for a hypothetical maximally exposed individual. Such a family-farm scenario, in which a family lives on the contaminated site and raises an appreciable fraction of its food on this site, is considered to be a credible bounding scenario by the NRC for assessments of waste disposal sites and by the DOE for decontaminated facilities. Even though such a scenario may be unlikely in the foreseeable future for the BOMARC Missile Site, it cannot be excluded as noncredible at some time several hundred years in the future.

The resident intruder is assumed to live continuously in a house on the BOMARC Missile Site and consume food products from a small subsistence garden located on the contaminated area. To provide an upper bound for potential doses, it has been assumed that all contaminated soil is available for transport through the environment. That is, the barriers presented by existing concrete and asphalt covers have been neglected. The soil concentrations used for the intruder scenario are not site average concentrations like those used for the off-site dispersion calculations discussed in Section 2.1. The intruder is assumed to be exposed to both the existing surface soil contamination in sub-area 1 and an additional amount of contamination resulting from excavation of the buried missile launcher. Contaminated soil that is excavated during the basement construction activities of the intruder-construction scenario (906 m^3) is assumed to be used as backfill around the house and spread around the house to a radius of about 25 m and a depth of 0.46 m, resulting in a contaminated surface area of 1,963 m^2. The total concentration of ^{239}Pu

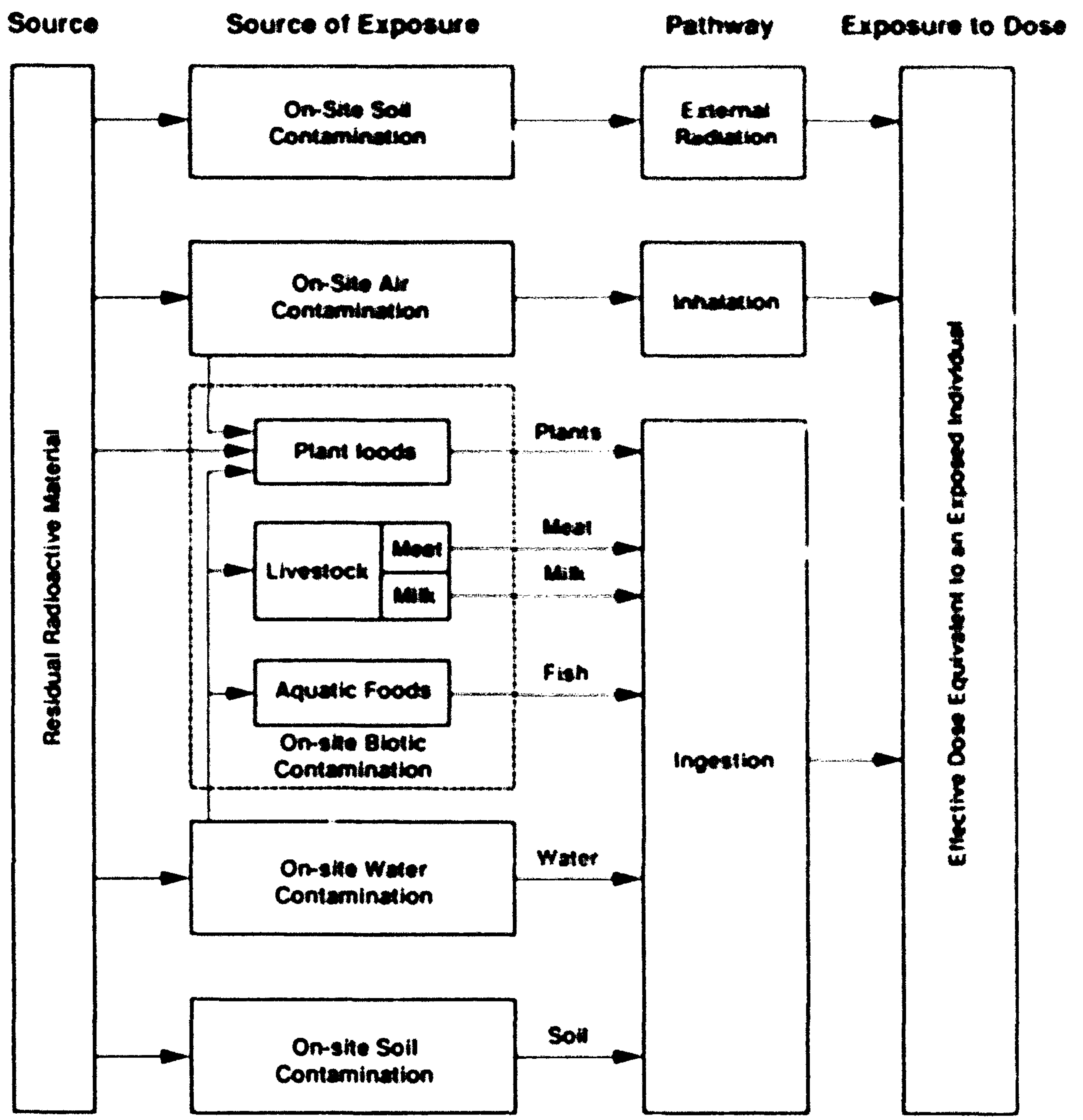
in this area from contamination associated with the launcher plus existing soil contamination would be 1,270 pCi/g to a depth of 0.46 m (the existing soil contamination levels in the basement excavation soil add less than 1% to this total activity). The area assumed for the resident portion of this scenario (1,963 m^2) and its associated contamination level (1,270 pCi/g) result in a higher dose than using the entire 16,000 m^2 of sub-area 1 and its lower average contamination level.

The farm family calculations were fully implemented in the RESRAD computer code. This code has been developed for the specific purpose of determining cleanup criteria for radioactively contaminated soils (Gilbert *et al.*, 1989). It contains all the potential pathways of exposure discussed in Section 1.1 except external exposure from immersion in a radioactive cloud. Version 4.10 of RESRAD was used for the EIS assessments.

The dose calculations performed by RESRAD are based on a pathway analysis method known as the concentration factor method (NRC, 1977; Till and Meyer, 1983). With this method, the relation between radionuclide concentrations in soil and the dose to a member of a population is expressed as a pathway sum, which consists of a sum of products of "pathway factors." Pathway factors connect compartments in the environment between which radionuclides can be transported or radiation transmitted (see Figure 3-2). Most pathway factors are steady-state ratios of concentrations in adjoining compartments. Some are factors for conversion from a radionuclide concentration to a radiation level or radiation dose, and others are use and occupancy factors that affect exposure. Each term in the sum corresponds to a pathway. A pathway factor can be added, deleted, or replaced without affecting the other pathways or pathway factors. This structuring facilitates the use of alternative models for different conditions or transport processes and the incorporation of additional pathways. Thus, RESRAD was easily tailored to model the situation at the BOMARC Missile Site.

For this assessment, values specific to the BOMARC Missile Site have been used wherever possible. Where site-specific data are not available the default values have been used. A list of all required RESRAD input appears in Annex 2. This list indicates both the "user input" and the "default" values. Site-specific input values were used wherever there were enough data about the BOMARC Missile Site to justify deviations from the default values.

Site specific values were used to describe the physical dimensions of the contaminated region (surface area, thickness, distance to groundwater) and the characteristics of the contamination (radionuclide concentrations present). The water balance parameters were also site-specific (evapotranspiration, precipitation, and runoff) as were the hydrogeolgic parameters for the contaminated, unsaturated, and saturated strata (total and effective porosities, hydraulic conductivities). Site-specific distribution coefficients (K_ds) for ^{241}Am and ^{239}Pu were selected to better represent the sandy soils of the BOMARC Missile Site. Many of the remaining RESRAD parameters describe the human behavior associated with potential radiation doses. These include breathing rate and dietary intake for the assumed exposure scenario. Exposure factors conforming to EPA risk assessment guidance were used for all these parameters (EPA, 1991).



Source: Modified from Gilbert et al, 1983.

FIGURE 3-2

EXPOSURE PATHWAY DIAGRAM FOR CALCULATING THE DOSE TO AN ON-SITE RESIDENT FROM RESIDUAL RADIOACTIVE MATERIAL

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Potential pathways of exposure included in this analysis are external radiation from contaminated ground as well as internal radiation from inhalation, ingestion of food, drinking water, and soil (see Figure 3-2). Both EDE and organ dose commitments are reported in the radiological assessments in the EIS. Consumption parameters were obtained from EPA (1991). Values for all input parameters used are listed in Annex 2 (RESRAD Input/Output). All summary output tables from RESRAD for this portion of the construction/resident scenario are also provided in Annex 2 of this appendix.

RESRAD calculations were initially made to simulate a total time period of 10,000 years. Calculated doses do not change significantly after a period of approximately 5,000 years, however, so a time period of 6,000 years was eventually used. Values for the year of maximum dose rate were used for estimating potential impact to intruders on the BOMARC Missile Site.

In all cases the maximum dose rate was given in the first year, represented by t = O in the tables in Annex 2. In subsequent years doses from surface contamination decreased because RESRAD treats the surface soil as eroding away with time.

Because plutonium is quite insoluble and immobile in the environment there are no significant contributions to estimated radiation doses via groundwater pathways until several hundred years have passed. The tables illustrating dose versus time in Annex 2 show the relative importance of groundwater pathways.

3.3 Sensitivity Analysis

The sensitivity of the RESRAD code to changes in parameter values was evaluated by using the sensitivity analysis capabilities of RESRAD. This consisted of varying a parameter over its nominal value by a preset amount and noting the change in code output. The code then graphically displays the output for the nominal value and the two extremes. For the purposes of this analysis, "code output" refers to the maximum calculated dose. This method does not yield a sophisticated quantification of sensitivity, but does give an indication of the impact that a single parameter has on the output of the code. Parameters in three categories were examined for their influence on the output of RESRAD. The categories are (1) physical site characteristics, (2) radionuclide-specific parameters, and (3) exposure pathway-specific parameters. The existing BOMARC site conditions were used as the base case; parameter values were varied around the values used for this scenario. Some subjective reasoning was used to limit the number of parameters examined. For instance, the water dependent pathway parameters were not examined except very grossly, because this pathway was not a significant factor in the BOMARC assessment. Also, the initial concentrations of radionuclides were not varied, because it is already known that the code output is linearly related to this input parameter.

Many of the RESRAD parameters affected specific pathway doses linearly - i.e., a two-fold increase in input value resulted in a two-fold increase in the pathway dose. Impact on the total dose then depended on the relative contribution of that pathway to the total dose. This is true of parameters such as inhalation rate and soil ingestion rate. Other parameters, such as erosion rate, significantly affected the total dose only when extreme values were used. Finally, the code appeared to be sensitive to changes in some parameters only over limited ranges of the parameter

value; thickness of the contaminated zone is an example of this group of parameters. The three categories of parameters are discussed in more detail below.

Physical Site Characteristics. The parameters in this category are in RESRAD menus 011 and 013. The parameters (and their nominal values) that were examined include:

Cover thickness (0 m)
Cover erosion rate (not used)
Cover density (not used)
Contaminated zone thickness (15.24 cm)
Contaminated zone erosion rate (.001 m/yr)
Area of contaminated zone (16,000 m^2)
Irrigation rate (0.2 m/yr).

The parameters in this category having the greatest impacts on the final dose were erosion rate of a cover and contaminated zone thickness. Cover thickness did not significantly affect the calculated dose unless the erosion rate of the cover was set to an extremely small value. Doing this had the dual effect of reducing the magnitude of the dose as well as delaying the time the maximum dose was received. For instance, using a cover thickness of 15 cm and changing the erosion rate by an order of magnitude had a minimal effect, but when the rate was decreased by a factor of one hundred (to a value of 1×10^{-5} m/yr) the maximum dose was reduced by a factor of five, and occurred at a time beyond 5,000 years.

When the contaminated zone thickness was reduced to a value of 7.6 cm (one-half the nominal value), the calculated dose decreased by a factor of two. Increasing the thickness, even to two meters, had little effect The cover density also had little effect on the calculated dose. This is presumably because the code treats the cover as if it were soil, and includes mixing of the cover and underlying contaminated zone regardless of cover density.

The contaminated zone erosion rate had an effect similar to that of the cover erosion rate. The contaminated zone area significantly affected the dose only when extremely low values were used (e.g., < 1 m^2). Finally, changes in the irrigation rate had an insignificant effect on the total dose.

Radionuclide-specific Parameters. A single parameter was examined in this category: the distribution coefficient (K_d). Changing the K_d for ^{239}Pu by an order of magnitude did not significantly change the calculated dose. Other radionuclide-specific parameters were judged to either have an authoritative source (e.g., dose conversion factors), or else they did not contribute significantly to the dose (e.g., bioaccumulation factors).

Pathway-specific Parameters. The parameters in this category are in menus 017 and 018 of RESRAD. Exposure pathways considered were inhalation and ingestion, which were the only significant exposure pathways. Within the ingestion pathway category, only ingestion of soil was significant, so other ingestion parameters were not examined. The parameters (and their nominal values) that were examined include:

Inhalation rate (7,000 m^3/yr)
Mass loading (0.0002 g/m^3)

Occupancy factor (0.55)
Soil ingestion (35 g/yr)
Mixing depth (15 cm)

As expected, calculated inhalation doses changed linearly with changes in values for the inhalation rate and mass loading. That is, a two-fold increase in either of these factors resulted in a two-fold increase in the code output. Occupancy factor, which relates time spent indoors to time spent outdoors, had a similar effect. Inhalation accounted for approximately 76% of the total dose, so the total dose increased (or decreased) slightly less than the increase (or decrease) in these factors.

The soil ingestion dose also changed linearly with soil ingestion rate. This pathway accounted for roughly 20% of the total dose, so doubling the value increased the total dose by approximately 20%.

Decreasing the depth of the topsoil mixing layer by a factor of two had no effect on the maximum total dose. However, increasing the value by a factor of two decreased both the inhalation and ingestion doses, resulting in a decrease of approximately a factor of two in the maximum total dose.

4.0 LEVEL OF IMPACT CRITERIA

Level of Impact (LOI) criteria for potential radiation doses were developed in order to categorize by magnitude the doses and risks to the public. The LOI used in this EIS are based on three factors: (1) comparison of estimated doses to applicable regulations, (2) comparison of estimated doses to natural radiation background, and (3) comparison of estimated increases in cancer incidence for population doses. Both regulatory limits for radiation doses and natural radiation background are expressed in terms of annual radiation dose. Because applicable regulations vary for different situations, different LOI criteria are required for occupational doses, population doses, and doses to individual members of the public (intruders).

4.1 LOI for Radiation Doses to Individual Members of the Public

The maximum allowable annual radiation dose for any individual member of the public is currently established by Federal NRC regulation to be 500 mrem in any single year (10 Code of Federal Regulations (CFR) 20). Proposed changes in this standard would reduce this limit to 100 mrem per year. In some circumstances more restrictive limits apply. In particular, releases from licensed low level radioactive waste sites can not exceed 25 mrem per year to any individual member of the public (10 CFR 61). Although this regulation pertains to NRC-licensed low-level radioactive waste disposal sites and therefore does not apply directly to the BOMARC Missile Site, this dose limit is useful in establishing LOI criteria.

The background radiation in the New Jersey area is about 180 mrem per year (EIS Section 3.9). This is the level of radiation dose in the environment to which members of the public would be exposed regardless of which alternative is selected. Estimated radiation dose from the BOMARC Missile Site is an increment added to this background radiation. Therefore, this dose rate is a useful benchmark in establishing LOI criteria.

The LOI criteria used here for annual radiation doses to any individual member of the public from one year of residence are:

NEGLIGIBLE	Estimated doses are equal to or less than 1 percent of background radiation (1.8 mrem).
LOW	Estimated doses exceed 1 percent of background radiation (1.8 mrem) but are equal to or less than 10 percent of background radiation (18 mrem).
MODERATE	Estimated doses exceed 10 percent of background radiation (18 mrem) but are equal to or less than 100 percent of background radiation (180 mrem). The low end of this range includes the performance standards for low level waste disposal sites (25 mrem). The high end of this range includes proposed NRC limits (100 mrem).
HIGH	Estimated doses exceed 100 percent of background radiation (180 mrem). This range includes current federal limits (500 mrem).

The criterion for NEGLIGIBLE level of impact is consistent with the recent NRC policy statement on releases of radioactivity considered to be Below Regulatory Concern (BRC) published in the Federal Register July 3, 1990 (55 FR 27522-37). Although this policy may never be finalized, the intent of the policy was to provide a basic framework for the development of new regulations that would exempt certain practices involving small quantities of radioactive materials from further regulatory controls. The heart of the NRC policy statement on BRC material was its individual and collective (population) dose criteria. The criterion for doses to members of the general public was one mrem per year. The criteria for collective dose are addressed in the following section.

4.2 LOI for Radiation Doses to the Surrounding Population

No maximum allowable annual radiation dose standards for radiation dose to populations have been established by Federal regulation. However, the statistical nature of radiogenic cancer induction allows potential excess cancers to be estimated from the collective radiation dose (expressed in person-rem). Therefore, this potential increase in the cancer rate is a useful benchmark in establishing LOI criteria.

The LOI criteria used here for annual collective radiation dose to the surrounding population from one year of residence are:

NEGLIGIBLE	Estimated doses are equal to or less than 10 percent of NRC BRC criterion (100 person-rem) corresponding to less than 0.03 excess cancers per year.
LOW	Estimated doses are greater than 100 person-rem per year (corresponding to greater than 0.03 excess cancers per year), but

equal to or less than the NRC BRC criterion (1,000 person-rem) corresponding to less than 0.3 excess cancers per year.

MODERATE Estimated doses are greater than 1000 person-rem per year (corresponding to greater than 0.3 excess cancers per year), but equal to or less than 10 times the NRC BRC criterion (10,000 person-rem) corresponding to less than 3 excess cancers per year.

HIGH Estimated doses exceed 10,000 person-rem (corresponding to 3 excess cancers per year).

The natural cancer incidence rate for a population of 9.3 million persons exceeds 25,000 fatal cancers per year. Therefore, 1000 person-rem to this population (the upper-bound criterion for an LOI of LOW) would correspond to an incremental increase in the overall cancer rate of 0.001 percent. The corresponding average increase in cancer risk to an individual in the affected population is about 0.3×10^{-7} per year, or 2.3×10^{-6} per lifetime.

All these criteria for levels of impact resulting from estimated collective dose to the surrounding population are far more restrictive than the NRC policy statement on releases of radioactivity considered to be BRC [*Federal Register*, July 3, 1990 (55 FR 27522-37)]. The intent of the NRC policy was to provide a basic framework for the development of new regulations that would exempt certain practices involving small quantities of radioactive materials from further regulatory controls. The heart of the NRC policy statement on BRC material was its individual and collective (population) dose criteria. The criterion for doses to individual members of the general public is addressed in the previous section.

The NRC criterion for collective dose is 1000 person-rem per year. In addition, the BRC policy statement indicated that the collective dose estimates used to determine compliance with the dose criterion would not need to include individual doses received at a rate of less than 0.1 mrem per year. Therefore, the method used in the analysis for this EIS, which includes all calculated doses no matter how smal' even if they are less than 0.1 mrem per year, is conservative (i.e., calculated doses are upper-bound).

5.0 REFERENCES

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APPENDIX 3-8

ANNEX 1

GENII OUTPUT, POPULATION DOSES

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-------------------------------------------------------------------------
                    GENII  Dose Calculation Program
                      (Version 1.485 3-Dec-90)

Case title:   BOMARC:  1995 POPULATION DOSE - BASELINE ASSESSMENT
Executed on:  04/23/92 at 15:26:22                          Page A.  1
-------------------------------------------------------------------------

          This is a far-field (wide-scale release, multiple site) scenario.
          Release is chronic
          Dose to exposed population of  9.236E+06

          THE FOLLOWING TRANSPORT MODES ARE CONSIDERED
               Air

          THE FOLLOWING EXPOSURE PATHS ARE CONSIDERED:
               Finite plume, external
               Ground, external
               Inhalation uptake
               Terrestrial foods ingestion
               Animal product ingestion
               Inadvertent soil ingestion

          THE FOLLOWING TIMES ARE USED:
               Intake ends after (yr):                50.0
               Dose calculations ends after (yr):     50.0
               Release ends after (yr):                1.0

========== FILENAMES AND TITLES OF FILES/LIBRARIES USED ====================

Input file name: \GENII\BASELINE.in                                  2-23-92
GENII DEFAULT PARAMETER VALUES                                       2-23-92
Radionuclide Master Library    (11/28/90 RAP)                       11-29-90
INEL GENII Food Transfer Factor Library - (ASR 15-May-90)            5-17-90
External Dose Factors for GENII in person Sv/yr per Bq/n (8-May-90 R 5-08-90
Internal Dose Increments, Worst Case Solubilities, 12/3/90 PDR      12-03-90
EXTGAM - Gamma Energies by Group for Finite Plume (13-May-90 RAP)    5-14-90
BOMARC POPULATION DISTRIBUTION - 1995 PROJECTION
McGuire Annual Star Data

===========================================================================

          -------- ----Release Terms------
          Release          Surface Buried
          Radio-   Air     Water   Source
          nuclide  uCi/yr  uCi/yr  uCi/m3
          -------- ------- ------- -------
          PU239    3.0E+02 0.0E+00 0.0E+00
          AM241    5.1E+01 0.0E+00 0.0E+00

========== AIR TRANSPORT ==================================================
          Joint frequency data input.
          Ground level release.

========== EXTERNAL EXPOSURE ==============================================
 8.8E+03  Hours of exposure to plume
 2.9E+03  Hours of exposure to ground contamination

========== INHALATION =====================================================
 8.8E+03  Hours of inhalation exposure per year
       1  Resuspension model:  1-Mass Loading, 2-Anspaugh
 1.0E-04  Mass loading factor (g/m3)
```

========== INGESTION POPULATION ==========

1 Atmospheric production definition: 1 - Use population-weighted chi/Q

Food production in region assumed to equal consumption.

========== TERRESTRIAL FOOD INGESTION ==========

FOOD TYPE	GROW TIME d	--IRRIGATION-- S *	RATE in/yr	TIME mo/yr	YIELD kg/m2	PROD-UCTION kg/yr	--CONSUMPTION-- HOLDUP d	RATE kg/yr
Leaf Veg	90.0	0	0.0	0.0	1.5		14.0	1.5E+01
Oth. Veg	90.0	0	0.0	0.0	4.0		14.0	1.4E+02
Fruit	90.0	0	0.0	0.0	2.0		14.0	6.4E+01
Cereals	90.0	0	0.0	0.0	0.8		180.0	7.2E+01

========== ANIMAL FOOD INGESTION ==========

FOOD TYPE	---HUMAN---- CONSUMPTION RATE kg/yr	HOLDUP d	TOTAL PROD-UCTION kg/yr	DRINK WATER CONTAM FRACT.	-------------STORED FEED------------- DIET FRAC-TION	GROW TIME d	-IRRIGATION-- S *	RATE in/yr	TIME mo/yr	YIELD kg/m3	STOR-AGE d
Meat	7.0E+01	34.0		0.00	0.3	90.00	0	0.0	0.0	0.80	180.0
Poultry	8.5E+00	34.0		0.00	1.0	90.00	0	0.0	0.0	0.80	180.0
Cow Milk	2.3E+02	4.0		0.00	0.3	45.00	0	0.0	0.0	2.00	100.0
Eggs	2.0E+01	18.0		0.00	1.0	90.00	0	0.0	0.0	0.80	180.0
					-------------FRESH FORAGE-------------						
Meat					0.75	45.0	0	0.0	0.0	2.00	100.0
Cow Milk					0.75	30.0	0	0.0	0.0	1.50	0.0

==========

Input prepared by: ______________________ Date: __________

Input checked by: ______________________ Date: __________

==========

6.4E-02 Population-weighted chi/Q

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: BOMARC: 1995 POPULATION DOSE - BASELINE ASSESSMENT
Executed on: 04/23/92 at 15:28:22 Page C. 1

Release period:	1.0
Uptake/exposure period:	50.0
Dose commitment period:	50.0
Dose units:	Person rem

Organ	Committed Dose Equivalent	Weighting Factors	Weighted Dose Equivalent
Gonads	7.0E-01	2.5E-01	1.8E-01
Breast	2.1E-05	1.5E-01	3.2E-06
R Marrow	3.9E+00	1.2E-01	4.7E-01
Lung	3.7E-01	1.2E-01	4.4E-02
Thyroid	2.1E-05	3.0E-02	6.4E-07
Bone Sur	5.1E+01	3.0E-02	1.5E+00
Liver	8.8E+00	6.0E-02	5.3E-01
LL Int.	6.1E-03	6.0E-02	3.7E-04
UL Int.	2.0E-03	6.0E-02	1.2E-04
S Int.	3.7E-04	6.0E-02	2.2E-05
Stomach	1.6E-04	6.0E-02	9.5E-06
Internal Effective Dose Equivalent			2.7E+00
External Dose			1.3E-07
Annual Effective Dose Equivalent			2.7E+00

Controlling Organ:	Bone Sur
Controlling Pathway:	Inh
Controlling Radionuclide:	PU239
Total Inhalation EDE:	2.6E+00
Total Ingestion EDE:	9.9E-02

```
------------------------------------------------------------------------
                    GENII  Dose Calculation Program
                      (Version 1.485 3-Dec-90)

Case title:   BOMARC:  1995 POPULATION DOSE - BASELINE ASSESSMENT
Executed on:  04/23/92 at 15:28:22                           Page C.  2
------------------------------------------------------------------------

Release period:                                                   1.0
Uptake/exposure period:                                          50.0
Dose commitment period:                                          50.0
Dose units:                                                Person rem



             Dose Commitment Year
                   1         2         3     ...
            ________________________________
Internal  : |
Intake    : |
Year:     3 |                      3.7E-04   ...
            |                         +
          2 |            3.7E-04   3.1E-04   ...              Internal
            |               +         +                       Effective
          1 |  1.2E-01 + 8.0E-02 + 7.9E-02 + ...  =  2.7E+00  Dose
                                                               Equivalent
                 ||        ||        ||
Internal                                                      Cumulative
Annual        1.2E-01 + 8.0E-02 + 7.9E-02 + ...  =  3.0E+00   Internal
Dose                                                          Dose
                 +         +         +                 +
External
Annual        1.3E-07   1.2E-07   1.2E-07    ...    5.6E-06
Dose
                 ||        ||        ||                ||
Annual                                                        Cumulative
Dose          1.2E-01 + 8.0E-02 + 7.9E-02 + ...  =  3.0E+00   Dose

                                                               Maximum
                                                    1.2E-01    Annual
                                                               Dose Occurred
                                                               In Year  1
```

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: BOMARC: 1995 POPULATION DOSE - BASELINE ASSESSMENT
Executed on: 04/23/92 at 15:28:22 Page C. 3

Release period:	1.0
Uptake/exposure period:	50.0
Dose commitment period:	50.0
Dose units:	Person rem

Committed Dose Equivalent by Exposure Pathway

Pathway	Lung	Stomach	S Int.	UL Int.	LL Int.	Bone Su	R Marro	Testes
Inhale	3.7E-01	3.4E-05	5.5E-05	2.2E-04	6.4E-04	4.9E+01	3.8E+00	6.8E-01
Leaf Veg	1.2E-07	1.8E-05	4.6E-05	2.6E-04	8.1E-04	2.7E-01	2.1E-02	3.8E-03
Oth. Veg	2.0E-07	3.2E-05	8.0E-05	4.5E-04	1.4E-03	4.7E-01	3.7E-02	6.6E-03
Fruit	6.4E-08	1.0E-05	2.5E-05	1.4E-04	4.4E-04	1.5E-01	1.2E-02	2.1E-03
Cereals	4.1E-07	6.4E-05	1.6E-04	9.1E-04	2.8E-03	9.4E-01	7.3E-02	1.3E-02
Meat	5.3E-11	7.8E-09	2.0E-08	1.1E-07	3.5E-07	1.1E-04	8.8E-06	1.6E-06
Poultry	2.5E-13	3.8E-11	9.6E-11	5.5E-10	1.7E-09	5.7E-07	4.4E-08	7.9E-09
Cow Milk	1.6E-11	2.4E-09	6.0E-09	3.4E-08	1.1E-07	3.5E-05	2.7E-06	4.8E-07
Eggs	2.9E-11	4.6E-09	1.1E-08	6.5E-08	2.0E-07	6.8E-05	5.3E-06	9.4E-07
Soil Ing	4.4E-10	6.8E-08	1.7E-07	9.7E-07	3.0E-06	1.0E-03	7.9E-05	1.4E-05
Total	3.7E-01	1.6E-04	3.7E-04	2.0E-03	6.1E-03	5.1E+01	3.9E+00	7.0E-01

Pathway	Ovaries	Muscle	Thyroid	Liver
Inhale	6.7E-01	2.1E-05	2.1E-05	8.5E+00
Leaf Veg	3.8E-03	1.3E-07	1.2E-07	4.8E-02
Oth. Veg	6.5E-03	2.2E-07	2.0E-07	8.3E-02
Fruit	2.1E-03	6.9E-08	6.3E-08	2.6E-02
Cereals	1.3E-02	4.6E-07	4.0E-07	1.7E-01
Meat	1.6E-06	6.6E-11	4.9E-11	2.0E-05
Poultry	7.8E-09	2.7E-13	2.4E-13	9.9E-08
Cow Milk	4.8E-07	1.9E-11	1.5E-11	6.1E-06
Eggs	9.4E-07	3.2E-11	2.9E-11	1.2E-05
Soil Ing	1.4E-05	4.7E-10	4.3E-10	1.8E-04
Total	7.0E-01	2.1E-05	2.1E-05	8.8E+00

Release period:	1.0
Uptake/exposure period:	50.0
Dose commitment period:	50.0
Dose units:	Person rem

External Dose by Exposure Pathway

Pathway	
Plume	1.0E-08
Sur Soil	1.2E-07
Total	1.3E-07

Case title: BOMARC: 1995 POPULATION DOSE - BASELINE ASSESSMENT
Executed on: 04/23/92 at 15:28:22

Release period:	1.0
Uptake/exposure period:	50.0
Dose commitment period:	50.0
Dose units:	Person rem

Cumulative Internal Dose to Organs by Exposure Pathway

Pathway	Lung	Stomach	S Int.	UL Int.	LL Int.	Bone Su	R Marro	Testes
Inhale	3.7E-01	3.4E-05	5.5E-05	2.2E-04	6.4E-04	4.9E+01	3.8E+00	6.8E-01
Leaf Veg	1.2E-07	1.8E-05	4.6E-05	2.6E-04	8.2E-04	2.7E-01	2.1E-02	3.8E-03
Oth. Veg	2.0E-07	3.2E-05	8.0E-05	4.6E-04	1.4E-03	4.8E-01	3.7E-02	6.6E-03
Fruit	6.4E-08	1.0E-05	2.5E-05	1.4E-04	4.4E-04	1.5E-01	1.2E-02	2.1E-03
Cereals	4.4E-06	6.6E-04	1.7E-03	9.5E-03	2.9E-02	6.0E+00	4.7E-01	7.8E-02
Meat	5.3E-11	7.9E-09	2.0E-08	1.1E-07	3.5E-07	1.1E-04	8.9E-06	1.6E-06
Poultry	2.5E-13	3.8E-11	9.6E-11	5.5E-10	1.7E-09	5.7E-07	4.4E-08	7.9E-09
Cow Milk	1.6E-11	2.4E-09	6.1E-09	3.5E-08	1.1E-07	3.5E-05	2.7E-06	4.9E-07
Eggs	2.9E-11	4.6E-09	1.2E-08	6.6E-08	2.0E-07	6.8E-05	5.3E-06	9.5E-07
Soil Ing	2.1E-08	3.2E-06	8.1E-06	4.6E-05	1.4E-04	2.8E-02	2.1E-03	3.5E-04
Total	3.7E-01	7.6E-04	1.9E-03	1.1E-02	3.3E-02	5.6E+01	4.3E+00	7.7E-01

Pathway	Ovaries	Muscle	Thyroid	Liver
Inhale	6.7E-01	2.1E-05	2.1E-05	8.5E+00
Leaf Veg	3.8E-03	1.3E-07	1.2E-07	4.8E-02
Oth. Veg	6.5E-03	2.2E-07	2.0E-07	8.3E-02
Fruit	2.1E-03	7.0E-08	6.3E-08	2.6E-02
Cereals	7.7E-02	5.3E-06	4.2E-06	1.2E+00
Meat	1.6E-06	6.6E-11	5.0E-11	2.0E-05
Poultry	7.8E-09	2.7E-13	2.4E-13	1.0E-07
Cow Milk	4.8E-07	1.9E-11	1.5E-11	6.2E-06
Eggs	9.4E-07	3.2E-11	2.9E-11	1.2E-05
Soil Ing	3.5E-04	2.2E-08	2.0E-08	5.5E-03
Total	7.6E-01	2.6E-05	2.5E-05	9.9E+00

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: BOMARC: 1995 POPULATION DOSE - BASELINE ASSESSMENT
Executed on: 04/23/92 at 15:28:22 Page C. 6

Release period:	1.0
Uptake/exposure period:	50.0
Dose commitment period:	50.0
Dose units:	Person rem

External Dose by Exposure Pathway

Pathway	
Plume	1.0E-08
Sur Soil	5.6E-06
Total	5.6E-06

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: BOMARC: 1995 POPULATION DOSE - BASELINE ASSESSMENT
Executed on: 04/23/92 at 15:28:22 Page C. 7

Release period:	1.0
Uptake/exposure period:	50.0
Dose commitment period:	50.0
Dose units:	Person rem

Committed Dose Equivalent by Radionuclide

Radionuclide	Lung	Stomach	S Int.	UL Int.	LL Int.	Bone Su	R Marro	Testes
AM 241	5.9E-02	3.0E-05	7.0E-05	3.9E-04	1.2E-03	7.5E+00	5.8E-01	1.0E-01
PU 239	3.1E-01	1.3E-04	3.0E-04	1.6E-03	5.0E-03	4.3E+01	3.3E+00	6.0E-01
Total	3.7E-01	1.6E-04	3.7E-04	2.0E-03	6.1E-03	5.1E+01	3.9E+00	7.0E-01

Radionuclide	Ovaries	Muscle	Thyroid	Liver
AM 241	1.0E-01	3.5E-06	3.3E-06	1.3E+00
PU 239	5.9E-01	1.8E-05	1.8E-05	7.5E+00
Total	7.0E-01	2.1E-05	2.1E-05	8.8E+00

External Dose by Radionuclide

Radionuclide	
AM 241	1.2E-07
PU 239	7.7E-09
Total	1.3E-07

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: BOMARC: 1995 POPULATION DOSE - BASELINE ASSESSMENT
Executed on: 04/23/92 at 15:28:22 Page C. 8

Release period:	1.0
Uptake/exposure period:	50.0
Dose commitment period:	50.0
Dose units:	Person rem

Cumulative Internal Dose to Organs by Radionuclide

Radionuclide	Lung	Stomach	S Int.	UL Int.	LL Int.	Bone Su	R Marro	Testes
AM 241	5.9E-02	3.1E-04	7.9E-04	4.5E-03	1.4E-02	9.8E+00	7.7E-01	1.4E-01
PU 239	3.1E-01	4.5E-04	1.1E-03	6.1E-03	1.9E-02	4.6E+01	3.6E+00	6.3E-01
Total	3.7E-01	7.6E-04	1.9E-03	1.1E-02	3.3E-02	5.6E+01	4.3E+00	7.7E-01

Radionuclide	Ovaries	Muscle	Thyroid	Liver
AM 241	1.3E-01	6.3E-06	5.1E-06	1.8E+00
PU 239	6.3E-01	2.0E-05	2.0E-05	8.1E+00
Total	7.6E-01	2.6E-05	2.5E-05	9.9E+00

External Dose by Radionuclide

Radionuclide	
AM 241	5.3E-06
PU 239	3.2E-07
Total	5.6E-06

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APPENDIX 3-8

ANNEX 2

RESRAD SUMMARY OUTPUT FOR INTRUDER-RESIDENT, UNRESTRICTED ACCESS ALTERNATIVE

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Summary : BOMARC BASELINE ASSESSMENT - 80 pCi/g (SUB-AREA 1)
File   : C:\BOMARC\AREA1.INP

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File : C:\BOMARC\AREA1.INP

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	1.600E+04	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	1.524E-01	1.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	1.750E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	4.000E+00	1.000E+02	---	BRLD
R011	Time since placement of material (yr)	3.100E+01	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	5.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	5.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	5.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	5.000E+03	3.000E+03	---	T(9)
R011	Times for calculations (yr)	6.000E+03	1.000E+04	---	T(10)
R012	Initial principal radionuclide (pCi/g): Am-241	1.356E+01	0.000E+00	---	S(2)
R012	Initial principal radionuclide (pCi/g): Pu-239	8.000E+01	0.000E+00	---	S(5)
R012	Concentration in groundwater (pCi/L): Am-241	not used	0.000E+00	---	W(2)
R012	Concentration in groundwater (pCi/L): Pu-239	not used	0.000E+00	---	W(5)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.600E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.600E+00	1.600E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.100E-01	4.000E-01	---	TPCZ
R013	Contaminated zone effective porosity	3.200E-01	2.000E-01	---	EPCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	4.900E+02	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	4.380E+00	5.300E+00	---	BCZ
R013	Evapotranspiration coefficient	6.100E-01	6.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.100E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	0.000E+00	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	5.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06	---	WAREA
R014	Density of saturated zone (g/cm**3)	1.600E+00	1.600E+00	---	DENSAQ
R014	Saturated zone total porosity	4.100E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	3.200E-01	2.000E-01	---	EPSZ
R014	Saturated zone hydraulic conductivity (m/yr)	4.900E+03	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	1.670E-03	2.000E-02	---	HGWT
R014	Saturated zone b parameter	4.380E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	3.600E+00	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R014	Individual's use of groundwater (m**3/yr)	1.500E+02	1.500E+02	---	UW
R015	Number of unsaturated zone strata	1	1	---	NS

Summary : BOMARC BASELINE ASSESSMENT - 80 pCi/g (SUB-AREA 1)
File : C:\BOMARC\AREA1.INP

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R015	Unsat. zone 1, thickness (m)	1.300E+01	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.600E+00	1.600E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	4.100E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	3.200E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	4.380E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	4.900E+03	1.000E+02	---	HCUZ(1)
R016	Distribution coefficients for Am-241				
R016	Contaminated zone (cm**3/g)	4.000E+02	2.000E+01	---	DCACTC(2)
R016	Unsaturated zone 1 (cm**3/g)	4.000E+02	2.000E+01	---	DCACTU(2,1)
R016	Saturated zone (cm**3/g)	4.000E+02	2.000E+01	---	DCACTS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.198E-03	RLEACH(2)
R016	Distribution coefficients for Pu-239				
R016	Contaminated zone (cm**3/g)	2.000E+04	2.000E+03	---	DCACTC(5)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+04	2.000E+03	---	DCACTU(5,1)
R016	Saturated zone (cm**3/g)	2.000E+04	2.000E+03	---	DCACTS(5)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	4.398E-05	RLEACH(5)
R016	Distribution coefficients for daughter Ac-227				
R016	Contaminated zone (cm**3/g)	2.000E+01	2.000E+01	---	DCACTC(1)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+01	2.000E+01	---	DCACTU(1,1)
R016	Saturated zone (cm**3/g)	2.000E+01	2.000E+01	---	DCACTS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	4.369E-02	RLEACH(1)
R016	Distribution coefficients for daughter Np-237				
R016	Contaminated zone (cm**3/g)	0.000E+00	0.000E+00	---	DCACTC(3)
R016	Unsaturated zone 1 (cm**3/g)	0.000E+00	0.000E+00	---	DCACTU(3,1)
RC16	Saturated zone (cm**3/g)	0.000E+00	0.000E+00	---	DCACTS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	6.626E+00	RLEACH(3)
R016	Distribution coefficients for daughter Pa-231				
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCACTC(4)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01	---	DCACTU(4,1)
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCACTS(4)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.755E-02	RLEACH(4)
R016	Distribution coefficients for daughter Th-229				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTC(6)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCACTU(6,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTS(6)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.466E-05	RLEACH(6)
R016	Distribution coefficients for daughter U-233				
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCACTC(7)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01	---	DCACTU(7,1)
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCACTS(7)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.755E-02	RLEACH(7)

Summary : BOMARC BASELINE ASSESSMENT - 80 pCi/g (SUB-AREA 1)
File : C:\BOMARC\AREA1.INP

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for daughter U-235				
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCACTC(8)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01	---	DCACTU(8,1)
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCACTS(8)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.755E-02	RLEACH(8)
R017	Inhalation rate (m**3/yr)	7.000E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	2.000E-04	2.000E-04	---	MLINH
R017	Dilution length for airborne dust, inhalation (m)	3.000E+00	3.000E+00	---	LM
R017	Occupancy factor, inhalation	5.500E-01	4.500E-01	---	FO3
R017	Occupancy and shielding factor, external gamma	6.000E-01	6.000E-01	---	FO1
R017	Shape factor, external gamma	-5.000E-01	1.000E+00	Negative shows SOILD used.	FS1
R017	Fractions of annular areas within AREA:				
R017	Outer annular radius (m) = √(1/π)	1.000E+00	1.000E+00	---	FRACA(1)
R017	Outer annular radius (m) = √(10/π)	1.000E+00	1.000E+00	---	FRACA(2)
R017	Outer annular radius (m) = √(20/π)	1.000E+00	1.000E+00	---	FRACA(3)
R017	Outer annular radius (m) = √(50/π)	9.500E-01	1.000E+00	---	FRACA(4)
R017	Outer annular radius (m) = √(100/π)	8.000E-01	1.000E+00	---	FRACA(5)
R017	Outer annular radius (m) = √(200/π)	7.500E-01	1.000E+00	---	FRACA(6)
R017	Outer annular radius (m) = √(500/π)	6.500E-01	1.000E+00	---	FRACA(7)
R017	Outer annular radius (m) = √(1000/π)	1.500E-01	1.000E+00	---	FRACA(8)
R017	Outer annular radius (m) = √(5000/π)	3.000E-02	1.000E+00	---	FRACA(9)
R017	Outer annular radius (m) = √(1.E+04/π)	2.000E-02	1.000E+00	---	FRACA(10)
R017	Outer annular radius (m) = √(1.E+05/π)	2.000E-02	0.000E+00	---	FRACA(11)
R017	Outer annular radius (m) = √(1.E+06/π)	1.000E-02	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	2.870E+01	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.400E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	1.020E+02	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	2.630E+01	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	0.000E+00	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	0.000E+00	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.500E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	7.000E+02	4.100E+02	---	DWI
R018	Fraction of drinking water from site	1.000E+00	1.000E+00	---	FDW
R018	Fraction of aquatic food from site	0.000E+00	5.000E-01	---	FR9
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	5.500E+01	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	1.600E+02	1.600E+02	---	LWI6
R019	Mass loading for foliar deposition (g/m**3)	1.000E-04	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Livestock water fraction from ground water	1.000E+00	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR

Summary : BOMARC BASELINE ASSESSMENT - 80 pCi/g (SUB-AREA 1)
File : C:\BOMARC\AREA1.INP

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	1.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	2.000E-08	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average annual wind speed (m/sec)	not used	2.000E+00	---	WIND
R021	Average building air exchange rate (1/hr)	not used	1.000E+00	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	1.000E+00	---	FAI
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR
R021	Building depth below ground surface (m)	not used	1.000E+00	---	DMFL
R021	Fraction of time spent indoors	5.000E-01	5.000E-01	---	FIND
R021	Fraction of time spent outdoors (on site)	2.500E-01	2.500E-01	---	FOTD
R021	Emanating power of Rn-222 gas	not used	2.000E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.000E-01	---	EMANA(2)

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation	active
3 -- plant ingestion	active
4 -- meat ingestion	active
5 -- milk ingestion	active
6 -- aquatic foods	active
7 -- drinking water	active
8 -- radon	suppressed
9 -- soil ingestion	active

Summary : BOMARC BASELINE ASSESSMENT - 80 pCi/g (SUB-AREA 1)

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Contaminated Zone Dimensions	
Area:	16000.00 square meters
Thickness:	0.15 meters
Cover Depth:	0.00 meters

Initial Soil Concentrations, pCi/g	
Am-241	1.356E+01
Pu-239	8.000E+01

Total Dose TDOSE(t), mrem/yr

Basic Radiation Dose Limit = 4 mrem/yr

Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03	5.000E+03	6.000E+03
TDOSE(t):	4.740E+01	4.736E+01	4.642E+01	4.471E+01	3.144E+01	1.571E+01	0.000E+00	0.000E+00	0.000E+00	8.227E-04
M(t):	1.185E+01	1.184E+01	1.161E+01	1.118E+01	7.860E+00	3.928E+00	0.000E+00	0.000E+00	0.000E+00	2.057E-04

Maximum TDOSE(t): 4.740E+01 mrem/yr   at t = 0.000E+00 years

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	9.449E-02	0.0020	5.304E+00	0.1119	0.000E+00	0.0000	7.073E-02	0.0015	3.070E-02	0.0006	4.815E-05	0.0000	1.602E+00	0.0338
Pu-239	5.514E-03	0.0001	3.069E+01	0.6475	0.000E+00	0.0000	3.987E-01	0.0084	1.731E-01	0.0037	2.714E-06	0.0000	9.030E+00	0.1905
Total	1.000E-01	0.0021	3.599E+01	0.7594	0.000E+00	0.0000	4.695E-01	0.0099	2.038E-01	0.0043	5.086E-05	0.0000	1.063E+01	0.2243

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.101E+00	0.1498
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.030E+01	0.8502
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.740E+01	1.0000

*Sum of all water independent and dependent pathways.

Summary : BOMARC BASELINE ASSESSMENT - 80 pCi/g (SUB-AREA 1)
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways

Radio-Nuclide	Ground mrem/yr	Ground fract.	Dust mrem/yr	Dust fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Am-241	9.413E-02	0.0020	5.284E+00	0.1116	0.000E+00	0.0000	7.010E-02	0.0015	3.046E-02	0.0006	4.778E-05	0.0000	1.596E+00	0.0337
Pu-239	5.510E-03	0.0001	3.069E+01	0.6479	0.000E+00	0.0000	3.967E-01	0.0084	1.724E-01	0.0036	2.704E-06	0.0000	9.029E+00	0.1906
Total	9.964E-02	0.0021	3.597E+01	0.7594	0.000E+00	0.0000	4.668E-01	0.0099	2.028E-01	0.0043	5.048E-05	0.0000	1.063E+01	0.2243

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.074E+00	0.1494
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.029E+01	0.8506
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.736E+01	1.0000

*Sum of all water independent and dependent pathways.

Summary : BOMARC BASELINE ASSESSMENT - 80 pCi/g (SUB-AREA 1)
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+00 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	9.271E-02	0.0020	5.114E+00	0.1102	0.000E+00	0.0000	6.736E-02	0.0015	2.932E-02	0.0006	4.599E-05	0.0000	1.544E+00	0.0333
Pu-239	5.491E-03	0.0001	3.015E+01	0.6494	0.000E+00	0.0000	3.869E-01	0.0083	1.684E-01	0.0036	2.641E-06	0.0000	8.870E+00	0.1911
Total	9.820E-02	0.0021	3.526E+01	0.7595	0.000E+00	0.0000	4.542E-01	0.0098	1.977E-01	0.0043	4.863E-05	0.0000	1.041E+01	0.2243

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.847E+00	0.1475
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.958E+01	0.8525
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.642E+01	1.0000

*Sum of all water independent and dependent pathways.

Summary : BOMARC BASELINE ASSESSMENT - 80 pCi/g (SUB-AREA 1)
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	9.097E-02	0.0020	4.847E+00	0.1084	0.000E+00	0.0000	6.385E-02	0.0014	2.779E-02	0.0006	4.359E-05	0.0000	1.464E+00	0.0327
Pu-239	5.467E-03	0.0001	2.911E+01	0.6511	0.000E+00	0.0000	3.736E-01	0.0084	1.626E-01	0.0036	2.551E-06	0.0000	8.566E+00	0.1916
Total	9.643E-02	0.0022	3.396E+01	0.7595	0.000E+00	0.0000	4.375E-01	0.0098	1.904E-01	0.0043	4.614E-05	0.0000	1.003E+01	0.2243

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.494E+00	0.1452
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.822E+01	0.8548
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.471E+01	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+01 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	7.812E-02	0.0025	2.994E+00	0.0952	0.000E+00	0.0000	3.944E-02	0.0013	1.717E-02	0.0005	2.693E-05	0.0000	9.043E-01	0.0288
Pu-239	5.190E-03	0.0002	2.087E+01	0.6639	0.000E+00	0.0000	2.679E-01	0.0085	1.166E-01	0.0037	1.829E-06	0.0000	6.142E+00	0.1954
Total	8.331E-02	0.0026	2.387E+01	0.7592	0.000E+00	0.0000	3.073E-01	0.0098	1.338E-01	0.0043	2.876E-05	0.0000	7.046E+00	0.2241

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+01 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.033E+00	0.1283
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.741E+01	0.8717
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.144E+01	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	6.327E-02	0.0040	1.267E+00	0.0806	0.000E+00	0.0000	1.669E-02	0.0011	7.265E-03	0.0005	1.139E-05	0.0000	3.827E-01	0.0244
Pu-239	4.408E-03	0.0003	1.064E+01	0.6774	0.000E+00	0.0000	1.366E-01	0.0087	5.945E-02	0.0038	9.328E-07	0.0000	3.132E+00	0.1993
Total	6.767E-02	0.0043	1.191E+01	0.7580	0.000E+00	0.0000	1.533E-01	0.0098	6.672E-02	0.0042	1.233E-05	0.0000	3.514E+00	0.2237

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.737E+00	0.1106
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.397E+01	0.8894
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.571E+01	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+02 years

Water Independent Pathways

Radio-Nuclide	Ground mrem/yr	Ground fract.	Dust mrem/yr	Dust fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+02 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

*Sum of all water independent and dependent pathways.

Summary : BOMARC BASELINE ASSESSMENT - 80 pCi/g (SUB-AREA 1)
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+03 years

Water Independent Pathways

Radio-Nuclide	Ground mrem/yr	Ground fract.	Dust mrem/yr	Dust fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+03 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 6.000E+03 years

Water Independent Pathways

Radio-Nuclide	Ground mrem/yr	Ground fract.	Dust mrem/yr	Dust fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 6.000E+03 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Am-241	5.026E-04	0.6109	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.777E-06	0.0046	5.624E-06	0.0068	5.120E-04	0.6223
Pu-239	3.075E-04	0.3738	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.311E-06	0.0028	9.281E-07	0.0011	3.107E-04	0.3777
Total	8.101E-04	0.9846	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.087E-06	0.0074	6.552E-06	0.0080	8.227E-04	1.0000

*Sum of all water independent and dependent pathways.

Summary : BOMARC BASELINE ASSESSMENT - 80 pCi/g (SUB-AREA 1)
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Dose/Source Ratios Summed Over All Pathways, (mrem/yr)/(pCi/g)

Nuclide (i)	t= 0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03	5.000E+03	6.000E+03
Am-241	5.237E-01	5.217E-01	5.050E-01	4.789E-01	2.974E-01	1.281E-01	0.000E+00	0.000E+00	0.000E+00	3.776E-05
Pu-239	5.037E-01	5.036E-01	4.947E-01	4.778E-01	3.426E-01	1.747E-01	0.000E+00	0.000E+00	0.000E+00	3.884E-06

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 4 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03	5.000E+03	6.000E+03
Am-241	7.638E+00	7.668E+00	7.921E+00	8.353E+00	1.345E+01	3.123E+01	*3.424E+12	*3.424E+12	*3.424E+12	1.059E+05
Pu-239	7.941E+00	7.942E+00	8.086E+00	8.373E+00	1.168E+01	2.290E+01	*6.203E+10	*6.203E+10	*6.203E+10	1.030E+06

*At specific activity limit

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 0.000E+00 years

Nuclide (i)	Initial pCi/g	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Am-241	1.356E+01	0.000E+00	5.237E-01	7.638E+00	5.237E-01	7.638E+00
Pu-239	8.000E+01	0.000E+00	5.037E-01	7.941E+00	5.037E-01	7.941E+00

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